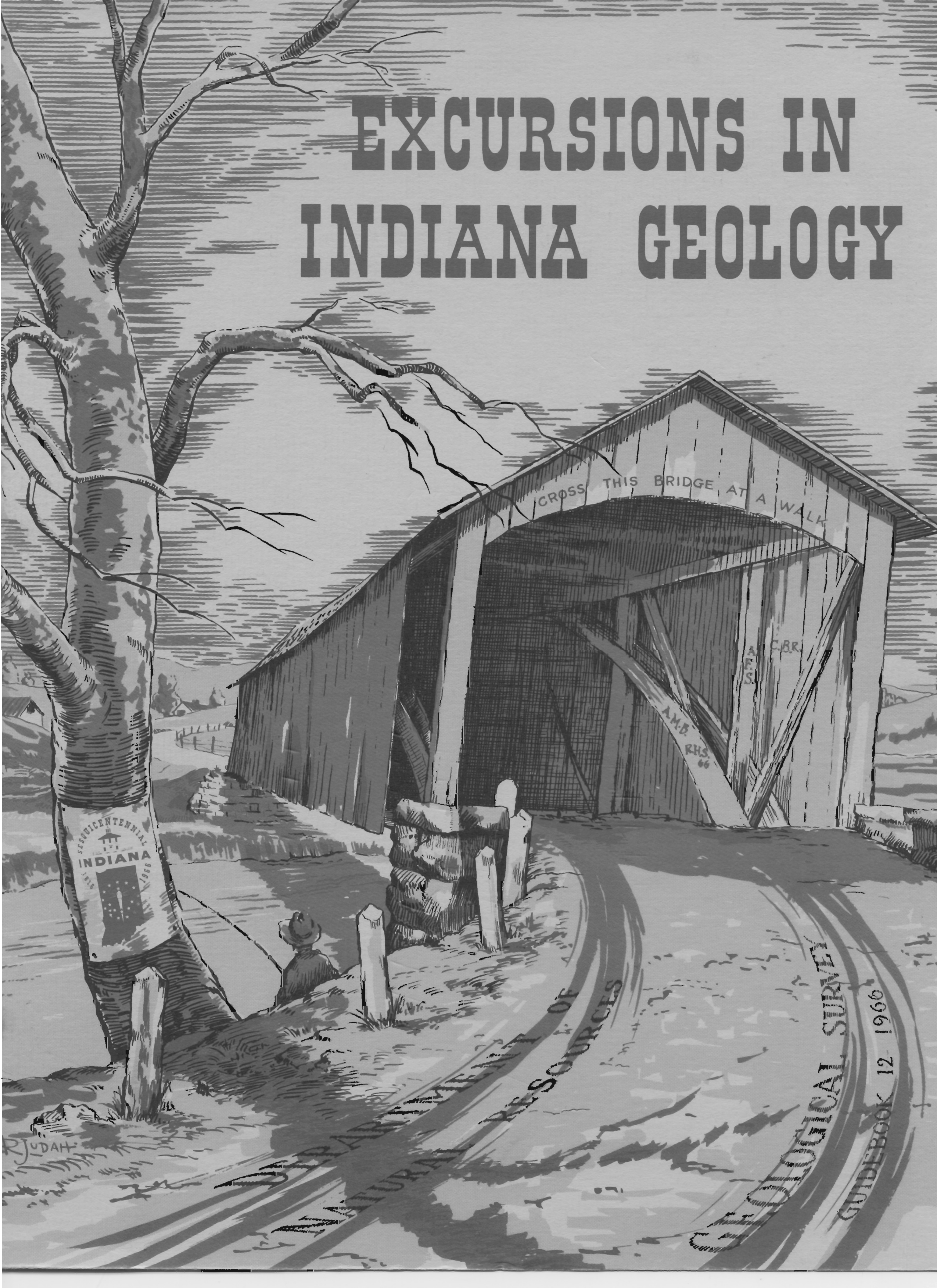
EXCURSIONS IN INDIANA GEOLOGY



DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY
GUIDEBOOK 12 1966

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POINT
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To Indianapolis
Sugar Cr.
Marietta
Blue River
Big Blue
Mt. Auburn
Lewis Cr.
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JOHNSON CO
BROWN CO
SHELBY CO
BARTHOLOMEW CO
Lake
Lemon
Beanblossom Cr.
Beanblossom
DINNER
STOP
Nashville
MONROE CO
BLOOMINGTON
MONROE
RESERVOIR
LAWRENCE CO
Creek
Oolitic
Bedford
Salt
JACKSON CO
JENNINGS CO
RIVER
Sand
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Eliza
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Seymour
Brownstown
Medora
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STOP
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Muscatatuck
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Millport
WASHINGTON CO
1
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135
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Excursions in Indiana Geology

By ANN M. BURGER, CARL B. REXROAD, ALLAN F. SCHNEIDER,
and ROBERT H. SHAVER

With contributions by LAWRENCE F. ROONEY *and* CHARLES E. WIER

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY GUIDEBOOK 12

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Excursions in Indiana Geology

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INTRODUCTION

Our purpose on these excursions arranged for the 58th meeting of the Association of American State Geologists is to bring about an awareness of Indiana geology and its attraction. Although our State lacks a Grand Canyon and production of glamour metals, features which in themselves would assure success of a field trip, it nevertheless offers many geologic challenges--challenges that we shall in part take up during these two days.

Our objective and our examples afield are diversified as are the interests in geology among our readers. Some examples stress the interrelationships of tectonism and stratigraphy. Others focus concepts from geomorphology, glacial geology, and economics on the way in which the State fulfills the needs of human habitation. Still other examples are excursions in an abstract sense and are in keeping with this Indiana Sesquicentennial year, whether dealing with economic geology and history of the stone and coal industries, with a historical perspective of our ever-increasing knowledge of glacial events, or with changing emphases in geologic endeavor.

Indiana lies wholly within the Central Lowland Province and thus calls to mind widespread, thin, nearly flat-lying Paleozoic rocks, major unconformities, and extensive plains. These features express epeirogenic submergences of the central part of the continent, long periods of general stability, and, nevertheless, repeatedly interrupted episodes of sedimentation and landform sculpture. Outstanding among these episodes was continental glaciation that carried to the Ohio River. Receiving ice from two principal directions, the State's surface nearly everywhere attests to its latest experience, most obviously in the form of a great till plain that is interrupted in its gross appearance by end moraines, valley trains, and ice-contact deposits.

Structurally, the State lies athwart a broad crestal area, the Cincinnati Arch, which separates the Michigan Basin on the north from the Illinois Basin on the southwest (fig. 1). Some structural instability, manifest as long ago as Precambrian time, is evident in such sedimentational or second-rank structural features as lithofacies, Silurian-Devonian and Mississippian-Pennsylvanian unconformities that change both locally and regionally in magnitude, and faulting.

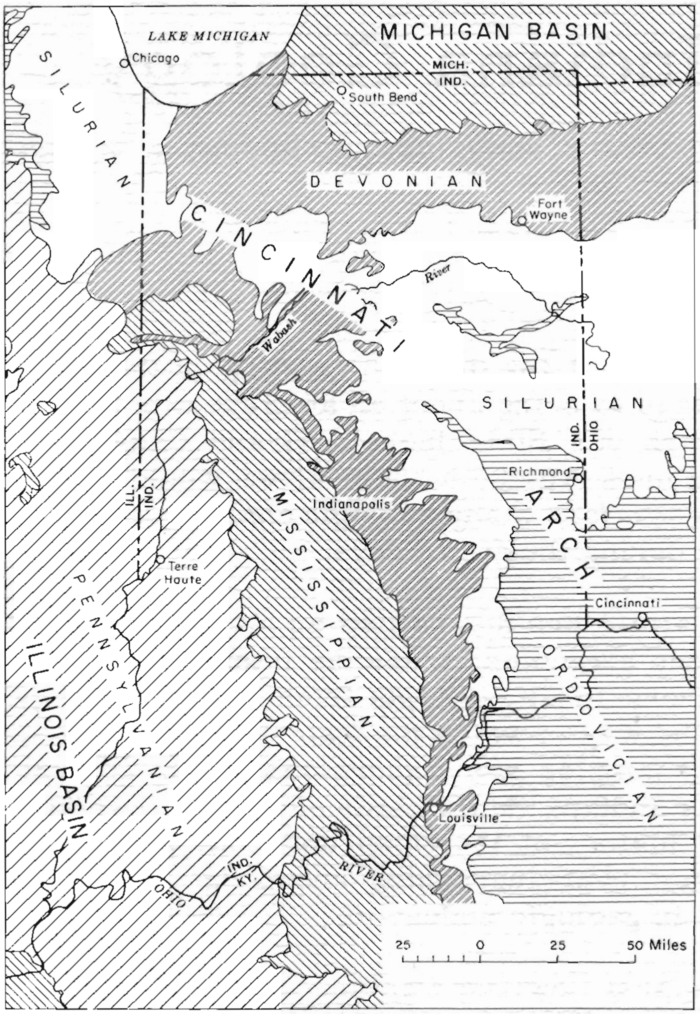


Figure 1. Generalized geologic map of Indiana and parts of adjoining states. Adapted from Pinsak and Shaver, 1964, fig. 1.

The more recent erosional record reflects structural history as well, and Paleozoic rocks from middle Ordovician to middle Pennsylvanian in age crop out at the bedrock surface according to their order of superposition (fig. 1). The Paleozoic units west and south of the Cincinnati Arch have special interest on these excursions. Their truncated edges, having differing resistances, are expressed alternately by open vales of gentle relief and uplands consisting of partly dissected westward-facing dip slopes and rugged forested scarps (back cover).

These cuestal features strike north by northwest and extend, exposed and beneath drift cover, from the Ohio River to the northeastern Illinois boundary. They afford access to abundant clays and shales, stone and cement materials, gypsum and coal; they are part of the topographic influence that directed the course of glacial ice, an influence causing the continental glaciers to cleave in the area north of Bloomington but at once allowing their lobes to push forward to the southern corners of the State. In such a geologic setting were founded many classic North American concepts in geology.

Within easy range of Bloomington we can demonstrate much of the variety of geologic form characteristic of the State. Crossing the regional strike and the boundary between driftless and glaciated areas, the first day's excursion (inside front cover) is generally eastward to traverse bedrock of Mississippian to Silurian age and drifts assigned to the Kansan, Illinoian, and Wisconsin Stages. It emphasizes the State's most widely known natural product, the Indiana Limestone, and relationships of physiography to bedrock and drift. The second day's excursion (inside back cover) is northwestward from Bloomington and crosses younger bedrock (to middle Pennsylvanian in age). It emphasizes the Mississippian-Pennsylvanian unconformity, stratigraphic relationships of drifts, and some of the newest methods of coal mining and land reclamation.

Primary responsibility for preparing this guidebook is as follows: Robert H. Shaver wrote the introduction and also was the administrative coordinator for the entire guidebook. Ann M. Burger prepared the first day's excursion from start through Stop 4 except for the discussion of Stop 1, written by Lawrence F. Rooney, and the explanations of Pleistocene geology, written by Allan F. Schneider. Schneider also prepared most of the remainder of the first day's trip. Carl B. Rexroad wrote most of the second day's excursion from start to Stop 3 except for the discussions of Pleistocene features at Stops 2 and 4 and the discussion preceding Stop 3, which were prepared by Schneider. Shaver prepared the remainder of the second day's trip except for the discussion of Stop 5 by Charles E. Wier.

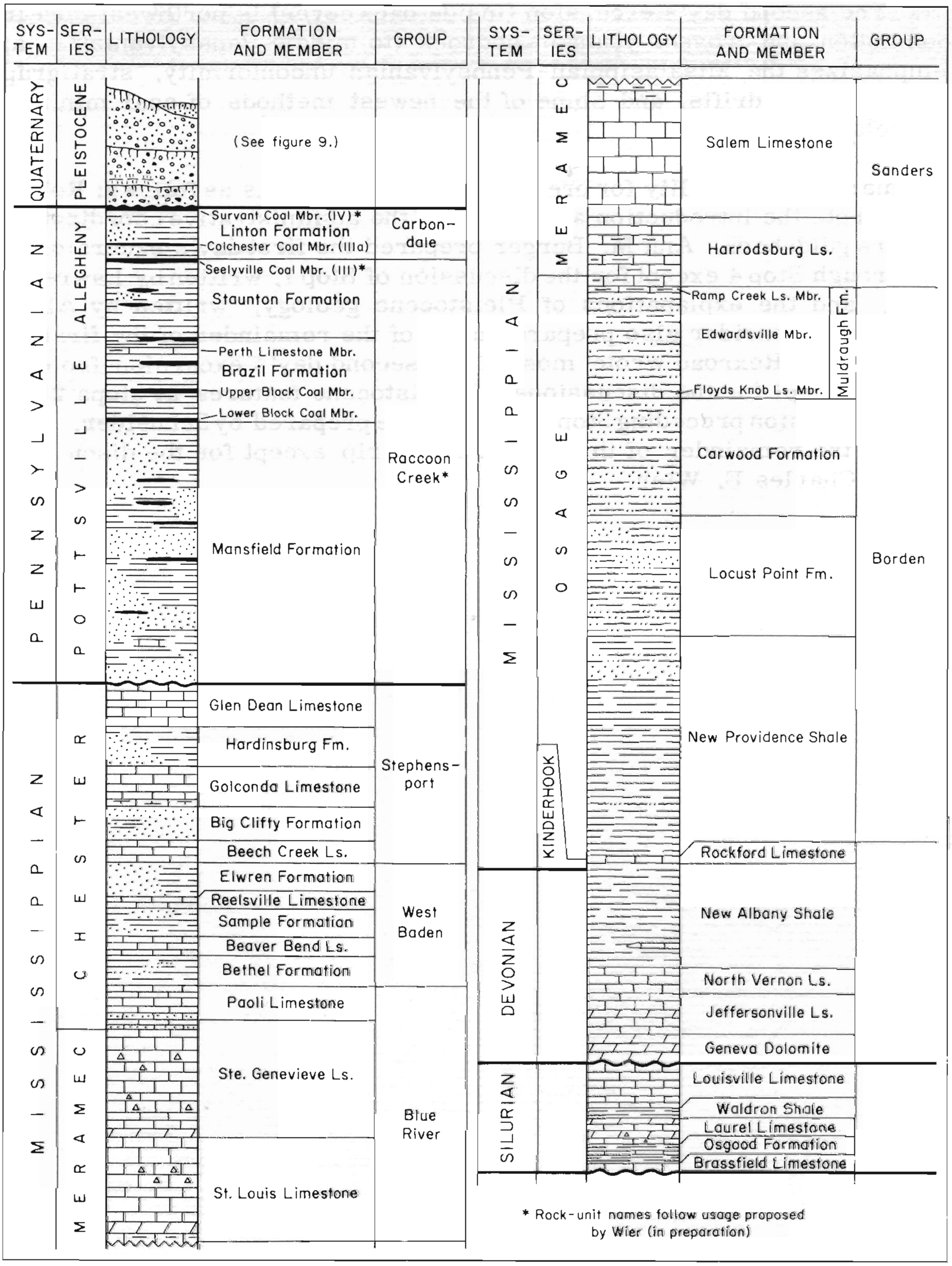


Figure 2. Columnar section showing outcropping rocks in the area of the field excursions. Vertical scale approximately 1 inch to 85 feet.

THE EXCURSIONS

First Day

Mileage

0.0 Leave north entrance of Indiana University Memorial Union Building, turning right (east) on Seventh Street.

The first part of this excursion is devoted to the world-famous Indiana Limestone, and the buildings of Indiana University and Bloomington are examples of concentrated use of this stone.

Known geologically as the Salem Limestone (middle Mississippian, fig. 2), the rock has been used in construction during the past 150 years, and the mode of its use is related both to the differing methods of quarrying and finishing and to changing architectural styles and economics. Currently the buff shades are more in demand for buildings than the gray unoxidized shades, but a combination of the two, called variegated facing, also is effective and attractive. Three basic textural grades of stone are: rustic, having very coarse texture; select, fine texture; and standard, intermediate between the two extremes. Both large panels and smaller rectangular and square blocks called ashlar are used in the buildings of this area. These smaller blocks may be split, giving a rough-hewn appearance to the stone, or sawed to a smoother finish. (See article on the Salem Limestone on p. 62.)

The University campus is an example of how continued use of this stone creates an impression of homogeneity and beauty, even though architectural styles have made a complete transition from traditional to contemporary during the 80 years that the campus has been at this location. The Union Building was constructed during two periods, and it is faced with variegated sawed random ashlar and variegated cut trim; the east (newer) wing is in traditional collegiate gothic style.

0.2 Showalter Fountain and Arts Center. Straight ahead in this cultural complex, the Auditorium is faced with chat-sawed random ashlar and trimmed with standard buff stone in a style between traditional and contemporary, although some gothic influence remains in detail. The Lilly Library (rare books, on the right) has stone like that of the Auditorium but in a style that is a step away from the traditional and that nevertheless retains a distinct classic influence. The Fine Arts Building is strictly contemporary in style but is in harmony with the other buildings. It is faced with variegated sawed random ashlar, but the pilasters and hand-cut fretwork are of select buff stone.

0.3 Turn right at blinking stoplight; turn left at next intersection and proceed 0.2 mile northward to Tenth Street. Turn left on Tenth Street at stoplight.

0.7 The new School of Business Building on right, in contemporary style, has variegated split face with standard buff trim on the lower part, but the upper panels are solely standard buff.

0.8 On the right is the Psychology Building, also in contemporary style and constructed of variegated random ashlar sawed stone.

0.9 Geology Building on the right. The standard panels of the Survey wing (east wing) have a gray smooth finish, but the upper part of the departmental wing has a sand-sawed finish.

1.6 Turn left (south) on Indiana Highway 37 (North College Street). Note Indiana Limestone construction of the Monroe County Courthouse built in the town square in 1908. This monolithic type of construction stands in distinct contrast with the more utilitarian buildings seen on the campus. The forerunner of this courthouse, built in 1819, had Salem limestone in the foundation and window sills; this was the first recorded use of this stone as a building material.

2.3 The two houses on the left are constructed of solid stone (rockfacing). This kind of stone, used mostly before 1900, is in contrast to the veneer stone now used in most residential construction. Turn right (west) at T-junction on Indiana Highway 45. In 0.2 mile turn left (south) on South Rogers Street and proceed 0.6 mile.

3.1 Radio Corporation of America plant, which assembles more color television sets than any other plant in the world. Splitface Indiana Limestone was used with blue ceramic-asbestos panels in the construction of this building.

3.6 Turn right (southwest) on Rockport Road, which extends southward here along the east flank of the Illinois Basin and along strike in the Mitchell Plain.

MITCHELL PLAIN: The Mitchell Plain is underlain by as much as 450 feet of middle Mississippian limestones (back cover) and is part of the large karst region that encompasses 1,125 square miles in Indiana and more than 2,850 square miles southward in Kentucky. Here we see the topographic expression of solution features produced in a humid Midwestern climate during several post-Paleozoic cycles, which also produced the cherty red (terra rosa) soils seen along the route. The characteristic karst features, such as caves, sinkholes, dolines, swallow holes, and dry stream beds, are particularly well developed on well-jointed rather dense St. Louis and Ste. Genevieve limestones (fig. 2) and, to a lesser degree, on the lower limestones. This karst plain has gradational eastern and western margins, is visibly terminated northward in central Indiana by a cover of glacial drift, but maintains some expression in the subdrift outcrop.

The earliest development of the Mitchell Plain was primarily by surface streams. Then rejuvenation and entrenching of the major through-flowing streams early in the Pleistocene Epoch permitted wide expanses of inter-stream areas to develop subterranean drainage, although notable flat areas having only slightly developed sinkholes remain. More extensive basins drain several square miles of the plain and contain numerous small sinks. At many places meandering lines of deep sinkholes mark the courses of former surface streams.

Older geologic studies of the Mitchell Plain contributed to the classic understanding of karst (Ashley and Kindle, 1903; Beede, 1911; Malott, 1922 and later), and studies of this kind are still being made (Powell, 1964). A new investigative emphasis has arisen, however, because the large number of subterranean passages in this limestone region have brought about unique problems in meeting present needs for water storage and supply. This is an emphasis with which the Indiana Geological Survey finds itself increasingly engaged (Gray and Powell, 1965).

The highest hills in this immediate area are capped by the thin-bedded argillaceous St. Louis Limestone; along valley walls the massive-appearing crossbedded Salem Limestone and the geode-bearing Harrodsburg Limestone crop out; siltstones and shales of the Borden Group (fig. 2) are exposed in the deeper valleys, and they represent the first fingers of dissection that encroach westward from the Norman Upland (fig. 3). In places the high areas are veneered with a cherty gravel, assigned to the Lafayette Gravel of Pliocene? age, a remnant of a Tertiary erosion cycle.

4.6 Along the route tall steel derricks rising above the wooded hills and jumbled piles of angular stone stand in mute testimony that this two-county area produces more building limestone than any other such area in the world. Ahead is one of the areas of concentrated quarrying, comprised of Indiana Limestone Co., Woolery Stone Co. (fig. 4), Carl Furst Co., and Bloomington Limestone Co. quarries.

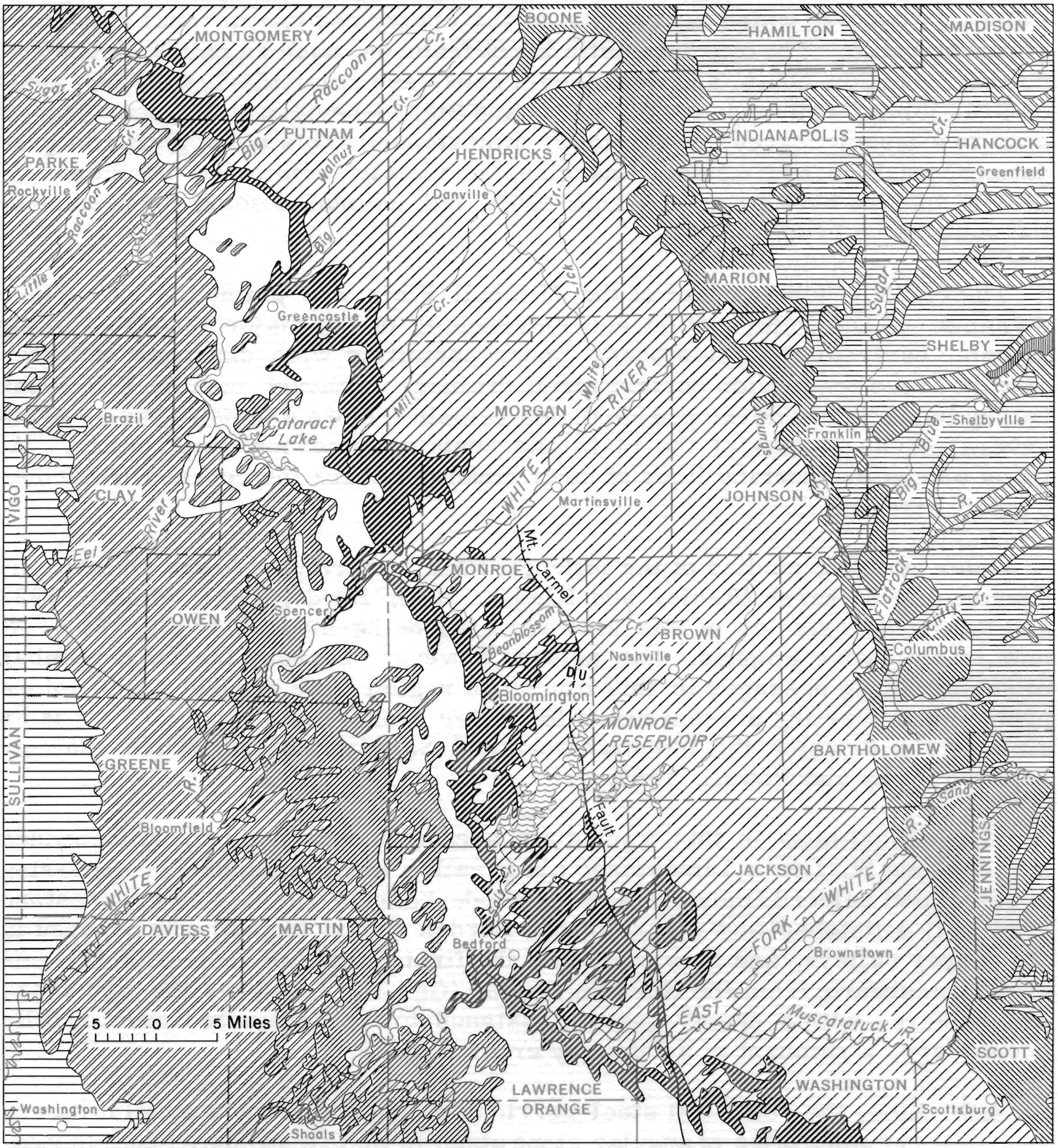
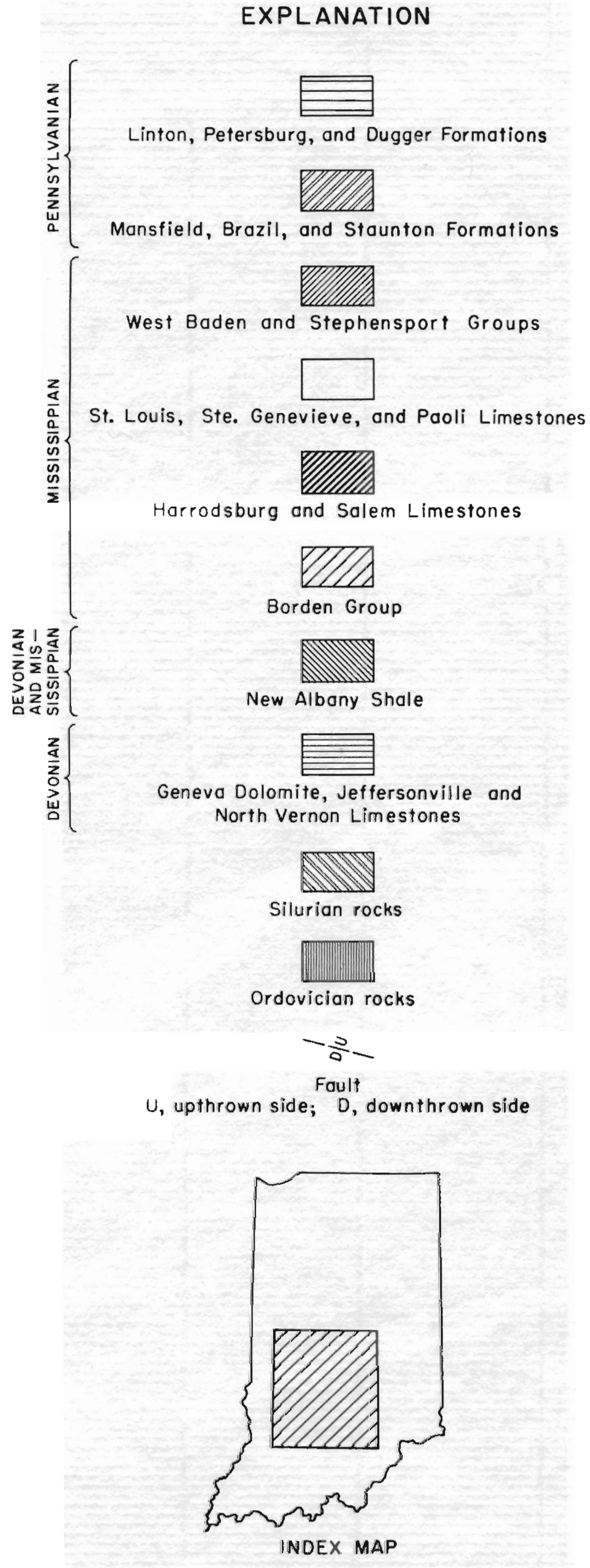


Figure 3. Map showing bedrock geology in the area of the field excursions. Compiled from Wier and Gray, 1961; Schneider and Gray, 1966; Gray, Wayne, and Wier, in preparation; and Lineback, in preparation.



Available records show that the first commerical quarry in the Salem Limestone opened in 1827, although the stone was used before that time.

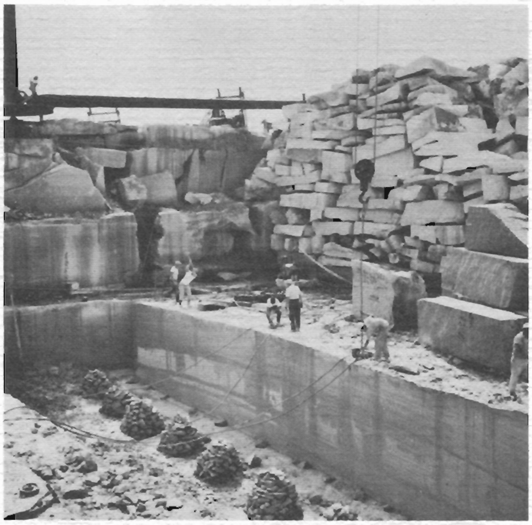
5.7 Limestone mill of the Bloomington Stone Co. is on the right, and orderly stockpiles of building stone on the left await rail transport.

6.4 Turn left (east) at crossroads and proceed 1.2 miles; turn right at stop sign; 0.6 mile to next entry.

8.3 The dry stone fence to the left of the road extends more than a mile to the east and to the south and is a monument to a bygone day. Seventy-nine years ago a man and boy hauled the stone from nearby quarries by horse and sled and built 2 rods of fence per day at construction costs of $2.50 per rod!

11.1 Active quarry ahead to right of road. Turn left (southeast) and proceed 0.6 mile; turn left (east) at T-junction and proceed 0.9 mile; turn left at stop sign, continue northward 0.1 mile, and turn right (south) onto Indiana Highway 37; 0.1 mile to next entry.

12.8 Channeled road cut in the Salem Limestone. In 1927, when the road was built, the Victor Oolitic Stone Co.



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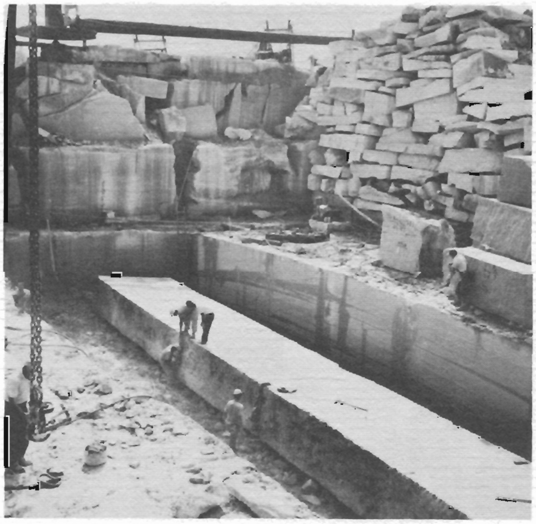

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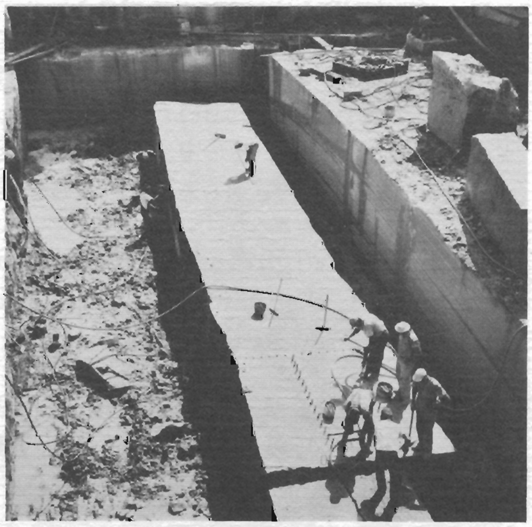

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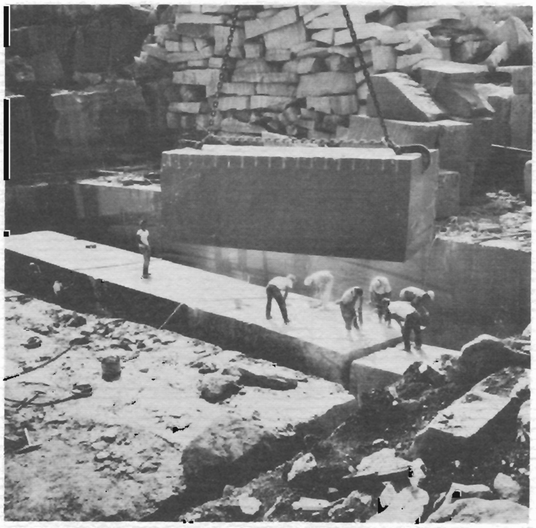

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volunteered to make this unique cut with their channel machines rather than have the Highway Department blast the stone, to avoid possible blast damage to their reserves on adjoining property. Although seldom invoked, a State law passed in 1905 forbids the use of dynamite in the Salem Limestone.

16.0 Slow. This road cut exposes the lower part of the crossbedded Salem Limestone (at the top of the hill), the more thinly bedded Harrodsburg Limestone, and the uppermost siltstones of the Borden Group. The Harrodsburg Limestone is an Indiana representative of the middle Mississippian limestones that in many eastern interior states yield abundant geodes known for their mineralogical variety and beauty.

17.4 Rounded symmetrical hill to left (Judah Hill) is capped by the Lafayette Gravel of Pliocene? age.

18.8 Characteristic karst topography developed on this limestone upland underlain by the St. Louis Limestone.

24.1 All the building stone for the Empire State Building was taken from a quarry about 1,000 feet east of the road here.

24.4 STOP 1, Perry, Matthews, and Buskirk Quarry of the Indiana Limestone Co. on the left (east) and the Walsh Quarry on the right. Sec. 33, T. 6 N., R. 1 W., Lawrence County.

Observations of quarrying methods will be followed by a trip to a mill.

We stand here on what is known as buff ridge, a valuable deposit in the Salem Limestone that the Indiana Limestone Co. hopes ultimately to quarry. Each quarry is a complex of rectangular trenches, called holes, some of which are more than 500 feet long and 80 feet deep. Some holes have been filled with waste blocks.

The first step in quarrying is the removal of the overburden, generally residual clay but in some places a part of the St. Louis Limestone. Most

Figure 4. Quarry operations in the Salem Limestone. After a vertical cut is made with a wire saw or channeling machine, horizontal holes are drilled at the base of the slab and wedges or "feathers" are driven into these holes. The piles of waste stone or "cushions" (A) serve to break the fall of the slab as it is dropped to its side by use of a cable-and-pulley system (B, C). The cable is removed (D) and pins are driven into the slab (E), which is then split into smaller blocks that are hoisted from the quarry (F) and transported to the mill. Photographs taken in Woolery Stone Co. quarry near Bloomington by R. D. Rarick.

clay can be scraped off by bulldozers, but the clay trapped in solution cavities, which are called grikes, remains to complicate quarrying of the upper ledges. Black powder is used to break up the St. Louis limestones.

After the overburden is removed, power-driven chisels mounted on tracks cut a pair of parallel channels about 2 inches wide, 10 feet deep, and 5 feet apart along the length of a proposed quarry hole. A second pair of channels is then cut at right angles to the length of the quarry hole so that a key block can be broken loose by wedging from the top. The block is then hoisted vertically. Succeeding blocks are removed by wedging and toppling until a canal about 10 feet deep and 8 feet wide extending the length of the quarry hole is created. Thus long blocks of stone adjacent to the canal can be channeled from the top, broken loose along the base by hand wedging, and toppled onto their sides for further segmenting and removal by the derricks (fig. 4). Most of the blocks carried to the mill or added to the waste piles weigh from 5 to 15 tons.

Only channelers were used at one time to cut stone from bedrock. Wire saws are now used extensively. A loop of $\frac{1}{4}$-inch wire is run from a power source to pulleys recessed in channels or drilled holes so that the wire can be drawn continuously across the stone. Sand fed onto the wires does the actual cutting.

For further discussion of Indiana's dimension limestone, refer to page 62.

Return to Indiana Highway 37, turn right (south), proceed 4.7 miles, and turn left (east) onto U. S. Highway 50 in Bedford; 7.0 miles to next entry.

36.1 Area of transition between the topographies that are separately characteristic of two physiographic units, the Mitchell Plain and the Norman Upland.

NORMAN UPLAND: The Norman Upland is a dissected area developed on the linear tract of westward-tilted dip slope of the Borden cuesta and on the eastward-facing scarp slope called the Knobstone Escarpment (back cover). Accordance of summits of the hills rising from 900 to slightly above 1,000 feet in altitude is evident. These summits are found commonly in interstream tracts away from main streams and are often said to be an Indiana expression of the Lexington Peneplain, a relic preserved from late Tertiary time. The broader of these uplands contrasts with the typical topography consisting of sharp ridges, steep-sloping valley sides, and narrow valley bottoms.

Along the gradational boundary between the Mitchell Plain and the Norman Upland, the intervalley tracts are veneered with the Harrodsburg Limestone, and these uplands *do* retain karst features common on the Mitchell Plain. The valleys, however, are cut into the siltstones of the Borden Group, and a more normal, mature dendritic pattern of dissection is evident (fig. 3). Because of the dual nature of the topography, the eastern boundary of the Mitchell Plain is drawn arbitrarily--where solution features lose their prominence.

40.6 Here the highway crosses the trace of the Mt. Carmel Fault, a gravity fault that strikes approximately N 10° W and is traceable for more than 50 miles (fig. 3). The vertical displacement is as much as 200 feet, and reversal of the regional southwestward dip is evident on both the upthrown (east) and downthrown sides. Reversal on the west side is associated with a series of small domes or anticlines, which provide the structural requisite of underground gas storage. The age of the faulting is not precisely known; Melhorn and Smith (1959), however, suggested that the faulting is related to the formation of the LaSalle Anticline in Illinois, dated as late Chester to early Pennsylvanian.

Because of the faulting, the width of the Borden outcrop and, therefore, also the width of the Norman Upland are greater than normal. The Salem and Harrodsburg Limestones, preserved on the downthrown side, are exposed in repeated outcrop just west of the fault along part of its extent.

46.2 STOP 2, Knobs Overlook. $SW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 10, T. 5 N., R. 3 E., Jackson County.

The Knobs Overlook is at the east edge of the Norman Upland and affords a good view of the most prominent physiographic break in the State of Indiana (fig. 5).

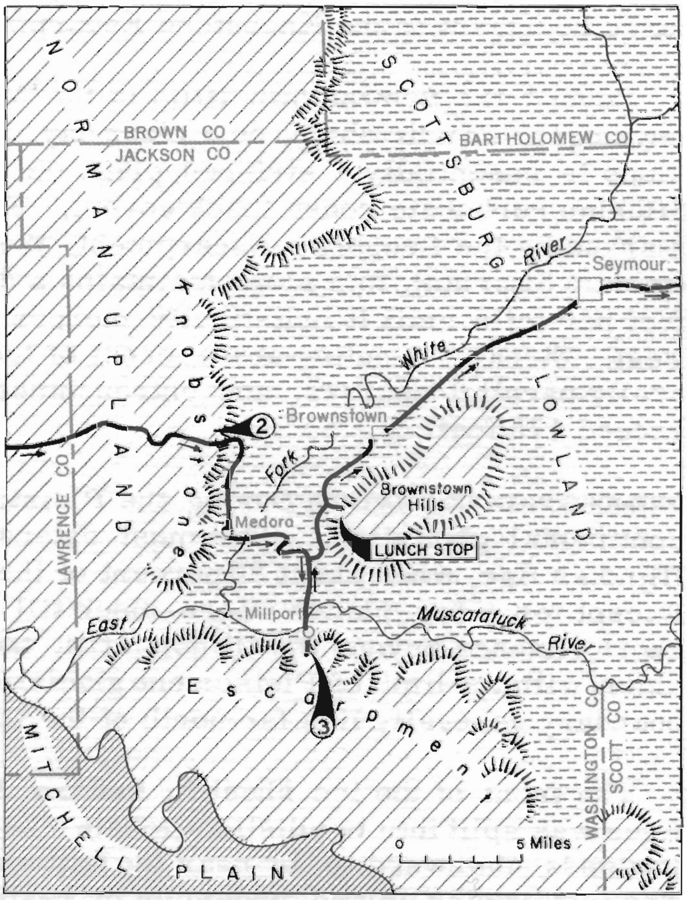

Figure 5. Map showing major physiographic features and route of AASG field trip near Brownstown.

KNOBSTONE ESCARPMENT, SCOTTSBURG LOWLAND, AND MUSCATATUCK REGIONAL SLOPE: It is along the Knobstone Escarpment that the resistant siltstones and sandstones of the upper part of the Borden Group give way eastward to the underlying New Providence and New Albany Shales (back cover). Differential weathering of these units has produced this prominent scarp here rising 300 feet above the glaciated Scottsburg Lowland to the east. Southward along the Ohio River, the escarpment has as much as 600 feet of relief. Extending thus from south of Louisville northward to the continental drift plain, the Knobstone forms one of our most rugged landforms. During the Pleistocene Epoch, it influenced the flow of the ice sheets; it has controlled regional drainage both in the past and present; and it has influenced the course of Indiana settlement.

From the Knobs Overlook and across the valley of the East Fork of White River, which occupies part of the Scottsburg Lowland here, the south end of an outlier of the Norman Upland known as the Brownstown Hills can be seen (fig. 5). These hills rise 300 feet above the lowland and have an area of 25 to 30 square miles. They were isolated from the main upland by the westward migration of the East Fork of White River north of its confluence with the Muscatatuck River. The Muscatatuck flows into the East Fork just east of the large reentrant in the Knobstone Escarpment that is south of this stop.

Beyond the Brownstown Hills is the Muscatatuck Regional Slope, another physiographic unit which, on a clear day, can be seen from the overlook. This slope is essentially a stripped plain on the westward-dipping Devonian and Silurian carbonate rocks (back cover). From its eastern boundary, which is marked by the Laughery Escarpment, there capped by the Laurel Limestone (middle Silurian), this slope maintains a dip to the west-southwest of about 15 feet per mile until it indistinctly merges with the Scottsburg Lowland to the west. Streams heading at the crest of the slope flow down the slope in generally parallel courses, and entrenchment of streams on the slope does not exceed 175 feet.

PRE-WISCONSIN GLACIATION: During the Pleistocene Epoch Indiana was the site of continental glaciation. The most extensive glaciation occurred during the Illinoian Age, when about 80 percent of the State was covered with ice (fig. 6). Except for a few places where older till of the Kansan Stage extends a very short distance beyond the Illinoian till, the Illinoian glacial boundary is coincident with the limit of Pleistocene glaciation in Indiana. The Wisconsin glacial boundary generally lies far north of the Illinoian boundary.

The front of the ice sheet in Indiana during both the Kansan and Illinoian Ages was split into two distinct lobate masses that followed bedrock-controlled lowlands southward to, or near the latitude of, the present Ohio River (fig. 6). The intervening upland, underlain by resistant Mississippian and lower Pennsylvanian rocks, formed a barrier that was glaciated only along its eastern and western peripheries. Thus the karst topography and the dissected terrane so characteristic of the bedrock-outcrop belts in south-central Indiana have been preserved without significant modification by glacier erosion or deposition. The Bloomington-Bedford quarry belt lies along the axis of this driftless upland near the north end of the Mitchell Plain, which plunges beneath the glacial margin more than 75 miles north of the southern limit of glaciation (fig. 6). The rugged Knobstone Escarpment along the east edge of the upland generally defines the boundary of the glaciated terrane to the east.

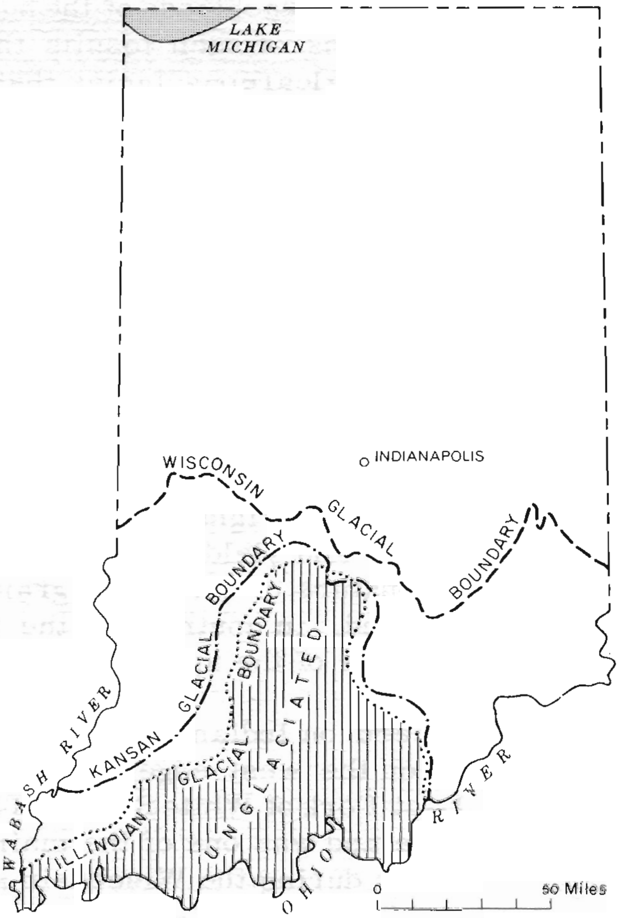

Figure 6. Map of Indiana showing glacial boundaries.

From the Knobs Overlook one can readily appreciate the importance of the Knobstone Escarpment in restricting the spread of the Kansan and Illinoian ice lobes as they pushed southward to the Ohio Valley. The Scottsburg Lowland to the east and the Muscatatuck Regional Slope beyond were completely buried beneath the ice. Although in many places the thickness of drift over preglacial upland tracts is no more than 5 or 10 feet, the average drift thickness is perhaps 20 to 25 feet. The thickness of the ice itself must have been considerable, however, to permit the ice to extend so far south. Indeed, at this locality and elsewhere along the west side of the lowland, the ice, at least during Illinoian time, actually overtopped the Knobstone Escarpment and spread westward for a short distance onto the Norman Upland. Here, however, the ice was apparently thin and relatively clean because it modified only slightly the preglacial topography of the upland; deposits of till are generally thin and patchy, and evidence of glacial erosion is difficult to find.

Leave Knobs Overlook, proceeding eastward on U. S. Highway 50. Exposed in the road cuts in the escarpment are the fine- to medium-grained clastic sediments of the upper part of the Borden Group. Here interbedded with hundreds of feet of sparsely fossiliferous Borden siltstone and shale is a thin calcareous bed containing abundant brachipods of the huge spiriferoid species *Syringothyris texta.* By means of such fossils the Borden was early correlated with a more calcareous facies that emerges on the west side of the Illinois Basin as the Burlington and Keokuk Limestones and the Warsaw Shale. General correlation also has been made with the biohermal sequences to the northwest that yield the world-famous Crawfordsville crinoid fauna.

47.8 Turn right (south) onto Indiana Highway 235, and from 0.1 to 0.9 mile cross a small area of Illinoian till that was not removed by stream erosion during the Sangamon Age nor by meltwater from the Wisconsin glacier as were most of the Illinoian deposits in this valley.

49.8 Clay pits on right are in the Locust Point Formation of the Borden Group and yield clay for making bricks. These clay shales show the nature of the finer grained clastic sediments underlying this lowland, in contrast to the medium-grained and more permeable clastics of the upland that erode more slowly.

50.9 Proceed on Indiana Highway 235 through the town of Medora, which is on the west edge of Wisconsin valley-train deposits along the East Fork of White River. The sluiceway here is more than 3 miles wide and was one of the main avenues of discharge of glacial meltwater during the Wisconsin and probably earlier glaciations.

52.8 This bridge over the East Fork of White River was built in 1875 and, being 434 feet long and having an additional 24 feet in overhang at each end, is the longest covered bridge in Indiana. It is one of three still in service on State highways and is the only remaining three-span wooden structure in the State.

Incidentally, the cover was not placed there for the comfort and protection of travelers (or horses) but simply to keep the timbers out of the weather. The cover is not an integral part of the structure but is merely tacked on. The success of this method of construction is shown by the fact that many covered bridges more than a century old are still in daily use, carrying loads several times what might have been expected when they were built.

54.1 Turn right (south) onto county road. Here, to the left of the road, is a conspicuous tract of sand dunes. Set against the Brownstown Hills east of a wide plain of glaciofluvial convergence, these dunes, although now stabilized, call to mind a late glacial episode in which an alluviating valley train, the prevailing westerly wind, and the Brownstown Hills barrier played the leading roles.

55.2 Turn left (east) onto county road entering main part of dunal area; turn right (south) in 1.5 miles onto Indiana Highway 135; 1.0 mile to next entry.

57.7 Area of Wisconsin lacustrine sediments, deposited when the Muscatatuck River was dammed by outwash deposits along the East Fork of White River or by windblown sand derived from these deposits. Ahead is the Knobstone Escarpment, which here forms the southern margin of the large reentrant in the escarpment (fig. 5).

59.5 Begin ascent of the Knobstone Escarpment, and 0.7 mile farther turn left (east) onto country lane; 0.1 mile to Stop 3.

60.3 STOP 3, overlook on Knobstone Escarpment at Millport. $SE\frac{1}{4}$ $NW\frac{1}{4}$ sec. 29, T. 4 N., R. 4 E., Washington County.

WHITHER THE ANCESTRAL OHIO?: The view from this part of the Knobstone Escarpment is to the north-northwest across the plain of convergence of the Muscatatuck River and the East Fork of White River (fig. 5). Here one may observe the angular sweep of the Knobstone to the west and north and the western extension of the Scottsburg Lowland into a large reentrant in the Norman Upland--an indentation certainly as large as that made by the present Ohio River to the south. The size of this northern reentrant strongly suggests that a large amount of pre-Pleistocene drainage was discharged through the gap. Much of the area of southeastern Indiana, including the Muscatatuck Regional Slope and the Dearborn Upland to the east, part of which is now drained by the present-day Ohio River, was probably included in the watershed of a pre-Pleistocene Muscatatuck River. Indeed, one may wonder if the Kentucky River also joined the Muscatatuck system and if the ancestral Ohio River itself did not here breach the Knobstone Escarpment during pre-Pleistocene and possibly early Pleistocene time. (See Gray and Powell, 1965, p. 22.) To say the least, the drainage through this gap probably was the major westward-flowing system in southeastern Indiana during late Tertiary time.

The section of Mississippian rocks in the road cut shows the characteristic fine- to medium-grained clastics of the Borden Group. These sediments are suggestive of the widespread deltaic conditions that were prevalent here during the Osage Epoch in contrast to the more normal marine conditions southward in Kentucky (Stockdale, 1939, p. 227-229) and westward in the subsurface, which we may reconstruct from the great biostromes of crinoidal limestones that are present in those directions. In Indiana, most of the bioherms yielding a renowned crinoid fauna seem to have built upward from the Floyds Knob Limestone Member into juxtaposition with the Edwardsville Member of the Muldraugh Formation (fig. 2).

Section along Indiana Highway 135 just south of Millport,
$SW\frac{1}{4}$ sec. 20 and $W\frac{1}{2}$ sec. 29, T. 4 N., R. 4 E., Washington County
[Modified from Sunderman, in preparation]

	Thickness (ft)
Tertiary and (or) Quaternary Systems, 15 ft:	
Residual soil, 15 ft:	
11. Clay, brownish-red; contains silicified blocks of the Harrodsburg Limestone	15.0
Mississippian System (Borden Group), 269.0 ft exposed:	
Muldraugh Formation, 62 ft:	
10. (Edwardsville Member) Siltstone, bluish-gray to light-brown, massive; small geodes at top of unit probably is at Muldraugh-Harrodsburg contact	57.0
9. (Floyds Knob Limestone Member) Limestone, brownish-red and light-brown, massive, dense, ferruginous; contains small quartz geodes	5.0
Carwood Formation, 135 ft?:	
8. Siltstone, bluish-gray, massive; fissile in lower 15 ft where weathered	26.0
7. Siltstone and limestone, reddish-brown and light-brown, thin-bedded; unit persists across entire face of this part of road cut for 300 to 400 ft	4.0
6. Siltstone, bluish-gray, medium-bedded, laminated, fissile where weathered	15.0
5. Siltstone, bluish-gray, massive; near middle has thin zones of crinoidal limestone containing brachiopods; about 10 to 15 ft of light-brown weathered siltstone follows contour of hill	35.0
4. Siltstone, light-brown, fissile, highly weathered	22.0
3. Covered interval (may contain Locust Point-Carwood contact)	33.0
Locust Point Formation, 72 ft exposed (see unit 3):	
2. Siltstone, bluish-gray, massive; light-brown and fissile where weathered; abundant worm-trail impressions on weathered bedding surfaces	22.0
1. Siltstone, light bluish-gray, fissile; many 4- to 6-inch iron-rich concretions and thin iron-rich bands	50.0
Total thickness of section	284.0

Retrace route north on Indiana Highway 135; in 3.1 miles turn right (east) at Vallonia Church onto county road; and 2.2 miles farther turn right (east) and proceed 0.3 mile to picnic area at Starve Hollow Lake.

65.9 LUNCH STOP, Starve Hollow Beach, Jackson-Washington State Forest. NE$\frac{1}{4}$ sec. 4, T. 4 N., R. 4 E., Jackson County.

Return to park entrance and proceed northward, traveling on blacktop road just west of the Brownstown Hills. Between here and Stop 4 much of the rather featureless character of the Scottsburg Lowland can be observed.

68.2 Turn right (northeast) onto Indiana Highway 135. Here is a northern extension of the dunal area along the western toe of the Brownstown Hills.

71.9 Turn right onto U. S. Highway 50. City of Brownstown.

77.9 Area north of the Brownstown Hills. To the southeast is the course along which the East Fork drainage flowed before westward migration of this drainage during late Tertiary time caused isolation of the hills. To the left is the broad valley train of the East Fork of White River.

85.8 Turn left (north) onto U. S. Highway 31 and cross area of Illinoian till east of the valley train.

91.8 Seventy-foot descent into valley of Sand Creek. Along this valley are both Recent alluvium and Wisconsin outwash deposits. The outwash deposits merge to the west with the valley-train deposits along the East Fork of White River (fig. 10).

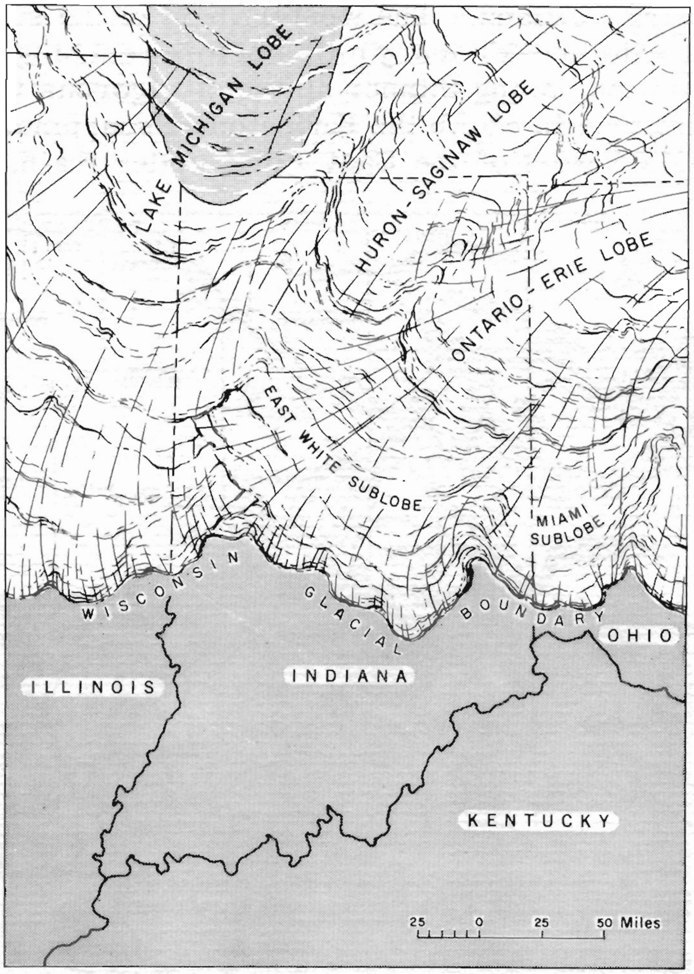

Figure 7. Map of Indiana and parts of adjoining states showing major ice lobes and sublobes during the Wisconsin Age. From Wayne, 1965a, fig. 1; terminology from Horberg and Anderson, 1956.

95.6 Ascend valley wall and cross the Wisconsin glacial boundary, partially concealed by a cover of dune sand.

WISCONSIN GLACIATION: The Wisconsin boundary here defines the southernmost penetration of glacier ice into Indiana during the Wisconsin Age; in fact, it marks the southernmost limit of continental Wisconsin glaciation anywhere in North America. North of this boundary Illinoian till is overlapped by the older of two Wisconsin tills deposited during the Tazewell Subage by the East White Sublobe (fig. 7) of the Ontario-Erie Lobe (Horberg and Anderson, 1956). Radiocarbon dates indicate an age of about 21,000 years for this older Wisconsin till.

The East White Sublobe entered this area from the north or northeast, flowing obliquely across the Muscatatuck Regional Slope and into the Scottsburg Lowland. The western part of the sublobe probably followed the lowland southward for many miles before reaching its terminal position. The Wisconsin ice, being thinner and less vigorous than the Illinoian, was unable at this latitude to climb the Knobstone Escarpment; no Wisconsin till has been identified west of the East Fork valley train. The west edge of the glacier was

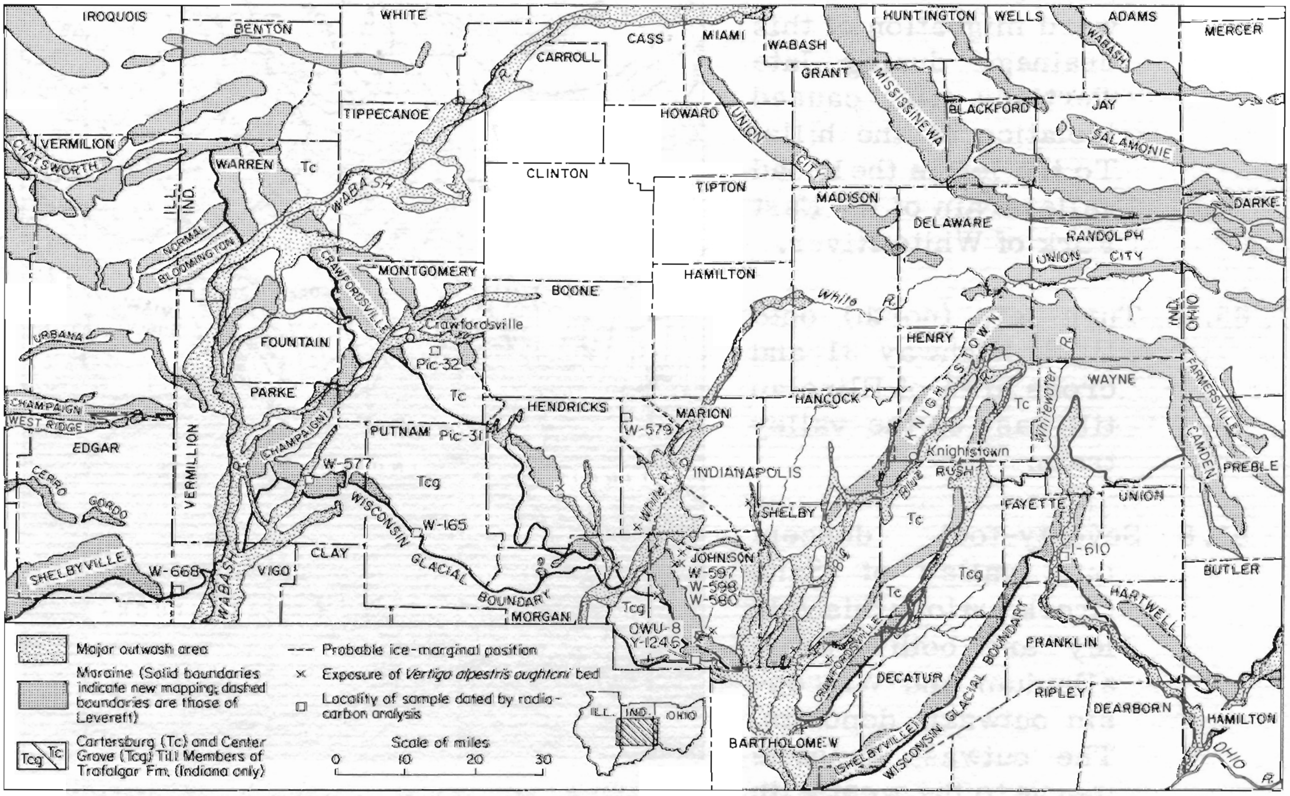

Figure 8. Map of central Indiana and adjoining parts of Illinois and Ohio showing moraines and other glacial deposits. Names in parentheses are Frank Leverett's names for moraines that have not been restudied; heavy lines indicate outer limits of Cartersburg and Center Grove Till Members of the Trafalgar Formation in Indiana. Adapted from Wayne, 1965a, fig. 2.

undoubtedly followed by a major ice-marginal stream confined between the ice on the east and the escarpment on the west. The influence of the bedrock physiography in controlling the movement of this early advance of the East White Sublobe is thus apparent. About 20 miles to the north, however, where the ice was more active than here, the Knobstone Escarpment was overridden.

The Wisconsin glacial boundary is marked in many places, though certainly not everywhere, by the outer edge of the Shelbyville Moraine. This moraine was named from a locality in Illinois and traced by Leverett (1899, p. 192-194; Leverett and Taylor, 1915, p. 77-80) through eastern Illinois and across Indiana to southwestern Fayette County in the eastern part of the State (fig. 8). Between here and Fayette County the Shelbyville Moraine is a belt of hummocky topography that rises only about 20 feet above the Illinoian ground moraine to the southeast. The Wisconsin boundary is readily discernible, however, because of the marked difference in materials and soils on opposite sides of the line. Leverett was so impressed by this change that he remarked that "for more than 40 miles... the border is so sharp and distinct that it can be located within a few yards" (Leverett and Taylor, 1915, p. 78).

CLASSIFICATION OF PLEISTOCENE SEDIMENTS: The Pleistocene deposits in Indiana have recently been subdivided into rock-stratigraphic units in accord with the principles of classification applied to other parts of the geologic column (Wayne, 1963). In Wayne's classification (fig. 9), which is followed by the State survey, the Kansan and Illinoian drifts are recognized, respectively, as the Cloverdale Till Member and Butlerville Till Member of the Jessup Formation. The only till units of Wisconsin age to be seen on this trip belong to the Trafalgar Formation, which consists of two members, the Center Grove Till Member and the younger Cartersburg Till Member. Deposits of stratified drift--such as outwash, lacustrine, and eolian sediments--are for the most part assigned to the Atherton Formation, but some--such as kame and esker deposits --are considered to be facies of other formations. Thus the genetic factors that historically have been used in Indiana--for example, those pertaining to

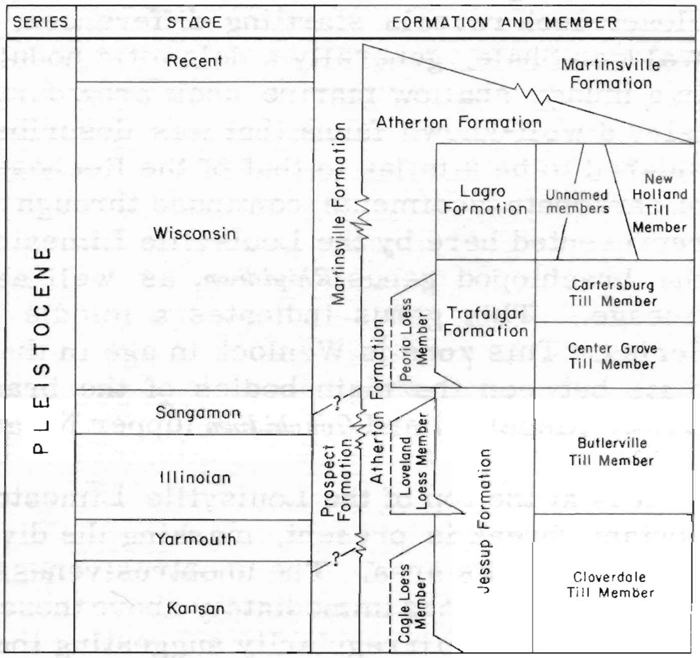

Figure 9. Pleistocene stratigraphic chart for Indiana. Adapted from Wayne, 1963, fig. 2.

geomorphic expression--are not the main controlling criteria in this classification.

97.0 Contact of dune sand and Wisconsin till (Center Grove Till Member).

97.7 Turn right (east) onto county road to Elizabethtown; proceed 2.2 miles, turning left (north) on first county road after crossing Indiana Highway 7; in 0.9 mile turn right (east) and proceed 1.2 miles. Turn right (east) into quarry.

102.0 STOP 4, Meshberger Stone Co. quarry. NE$\frac{1}{4}$ sec. 6, T. 8 N., R. 7 E., Bartholomew County.

Quarry operations here in the drift-covered area of transition between the Scottsburg Lowland and the Muscatatuck Regional Slope have exposed bedrock units that underlie parts of both of these physiographic regions. The New Albany Shale, a widespread carbon-rich brittle shale correlated with the Chattanooga Shale of Tennessee and the Antrim Shale of Michigan, is exposed in the upper few feet of the bedrock section and underlies much of the Scottsburg Lowland to the west. The carbonate section in the quarry consists of both Devonian and Niagaran (middle Silurian) limestones and dolomites which underlie part of the Muscatatuck Regional Slope to the east.

At first glance this carbonate section seems to be quite homogenous, but a closer look reveals startling differences. In the sump of the quarry is the Waldron Shale, generally a dolomitic nodular shale. This unit was deposited in a muddy shallow marine shelf area during middle Niagaran time and contains a well-known fauna that was described by James Hall in 1882 and considered to be similar to that of the Rochester Shale of New York. Deposition of carbonate sediments continued through the rest of middle Niagaran time, represented here by the Louisville Limestone, which in some places contains the brachiopod genus *Rhipidium*, as well as other forms in the pentamerid lineage. This genus indicates a middle brachiopod zone in the Niagaran Series. This zone is Wenlock in age in the British standard and is intermediate between the main bodies of the brachiopod zones of *Pentamerus oblongus* (lower Niagaran) and *Conchidium* (upper Niagaran).

It is at the top of the Louisville Limestone that an inconspicuous, yet important, break is present, marking the division of the Silurian and Devonian Systems in this area. The unobtrusiveness of this boundary is quite remarkable, for the rocks immediately above those of middle Niagaran age are middle Devonian; yet no irregularity suggesting the presence of such an unconformity can be observed. This unconformity is time transgressive from south to north along regional strike, the Devonian strata resting on Cayugan (upper Silurian) rocks in northern Indiana and on lower Niagaran rocks in southern Indiana.

	Thickness (ft)
Devonian System, 81. 3 ft:	
New Albany Shale, 3. 0 ft:	
10. Shale, dark brownish-gray to gray	3. 0
North Vernon Limestone, 2. 6 ft:	
9. Limestone, fossiliferous; upper part dark gray, dense, fossiliferous; lower part gray to tan, coarsely crystalline	2. 6
Jeffersonville Limestone, 45. 8 ft:	
8. Limestone, tan; upper 3. 0 ft crystalline, medium bedded, fossiliferous; lower 4. 4 ft mottled, fine grained, containing fossil detritus; zone of nodular chert near base (*Paraspirifer acuminatus* Zone)	7. 4
7. Limestone in alternating units of tan, brown, and gray color, dolomitic, dense to granular and porous in texture; in places containing breccia and black shale partings; lower part laminated	12. 3
6. Dolomite and limestone, alternating in few-foot intervals, light-tan to brown and gray, banded, chalky, dense in places; lower 1. 7 ft gray to dark gray-brown, massive to dense, containing dark-colored bands, stylolitic partings, scattered calcite crystals, and pyrite in vuggy spaces	13. 9
5. Limestone, light-gray to light-brown, dolomitic, dense to granular; contains stromatoporoids, trilobites, brachiopods, cup corals, and other fossils; vugs and solution cavities in lower 3. 3 ft (coral zone)	12. 2
Geneva Dolomite, 29. 9 ft:	
4. Dolomite, brownish-gray to chocolate-brown, fine-grained to saccharoidal, massive; contains small pockets of calcite	3. 8
3. Dolomite, medium-brown to chocolate-brown, granular to saccharoidal, massive; contains large masses of white to yellow coarsely crystalline calcite; dolomitized coral molds and casts in 2- to 3-ft zone 2. 6 ft below top of unit; pyrite in places abundant	26. 1
Silurian System, about 30 ft exposed:	
Louisville Limestone, 21. 2 ft:	
2. Limestone, dark medium-gray, fine-grained, crystalline, massive, dolomitic; stylolites common	21. 2
Waldron Shale, about 8 ft exposed or in water:	
1. Shale, gray to bluish-gray, dolomitic, fossiliferous	8. 0
Total thickness (approximate) of section	140. 5

Return to quarry entrance and turn right (north); proceed 0.4 mile and turn right (east) at Shiloh Church onto Indiana Highway 9. Follow this highway where it turns left (north) in 0.9 mile and proceed 4.2 miles northward across western part of the glaciated Muscatatuck Regional Slope (fig. 10). Well records and refraction seismic shots indicate that the thickness of glacial deposits in this area averages about 30 feet but is as much as 100 feet over buried bedrock valleys.

107.5 Cross Clifty Creek. Just north of Clifty Creek the route passes from the older Wisconsin till (Center Grove Till Member of the Trafalgar Formation) onto the younger Wisconsin till (Cartersburg Till Member). The two units are separated from each other by a thin fossiliferous silt bed, called the *Vertigo alpestris oughtoni* bed by Wayne (1963), that has been traced more than half way across the State (fig. 8), that is, a distance of about 80 miles around the margin of the younger (Cartersburg) till. This silt has yielded several species of mollusks, mostly snails, and also contains wood that has been dated by radiocarbon method as about 20,000 years old. It almost certainly represents a distinct though brief withdrawal of the East White Sublobe, during which time a subarctic flora and fauna began to inhabit the area.

The belt of undulating topography just north of Clifty Creek has long been considered to be part of the Champaign Morainic System of Leverett (1899, p. 223-240; Leverett and Taylor, 1915, p. 87-93), which has recently been renamed the Crawfordsville Moraine (Wayne, 1965a) in parts of Indiana (fig. 8). (See p. 49 for a more complete discussion.)

112.0 Enter village of Hope, proceed northward 1.5 miles, and turn left (west) onto county road, following it for 2.5 miles and passing across ground moraine on the upper (Cartersburg) of the two Wisconsin tills in the Trafalgar Formation.

116.0 Turn right (north) at T-intersection. To the west and northwest is a belt of hilly topography, which can perhaps best be seen about 1.7 miles north of the turn. These hills constitute an isolated segment of end moraine (figs. 8 and 10), the exact origin of which is not yet clear. Possibly the moraine was deposited in a reentrant in the East White Sublobe; possibly it represents a recessional stand of the ice as it retreated from the terminal position marked by the edge of the upper (Cartersburg) till sheet.

119.1 Turn left (west) at stop sign onto Indiana Highway 252 and proceed 0.5 mile to the village of Flat Rock, which is built on the broad, low valley-train terrace along Flatrock Creek (fig. 10). Continue westward for 1.8 miles, crossing Flatrock Creek, then its tributary Lewis Creek, and ascending the low scarp that separates floodplain from terrace. Flatrock Creek is the easternmost of several southwestward- to southward-flowing streams of the Upper East Fork Drainage Basin to be crossed in an east-west distance of about 10 miles. Most of these streams flow in wide ill-defined valleys, which are floored with generally thin alluvial deposits underlain by thick outwash sediments (fig. 10) derived mainly from the wasting East White Sublobe near the close of the Tazewell Subage. The width of the terrace along Flatrock Creek, including the narrow floodplain, is about 3 miles at this latitude.

121.4 Turn right (north) at T-intersection onto county road and proceed northward on low outwash terrace between floodplain of Lewis Creek on the right and base of morainic segment on the left. The moraine trends in a general north to northeast direction; it is about 7 miles long by $3\frac{1}{2}$ miles wide and is virtually encircled by valley-train deposits (fig. 10).

122.5 Turn left (west) at T-intersection and rise onto the moraine. Both Center Grove and Cartersburg tills are known to be present in the moraine.

123.5 Turn right (north) at intersection. The elevation of the moraine here is 100 feet above the floodplain of Lewis Creek; a mile to the west the crest of the moraine is another 100 feet higher.

125.1 STOP 5, Mt. Auburn Kame. $SE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 17, T. 11 N., R. 6 E., Shelby County.

Although the moraine is apparently built mainly of till and therefore is not a kame moraine in the ordinary sense, it is marked by an uncommon number of exemplary kames (fig. 10). The hill directly to the west is the highest and most massive kame in the moraine; the top of the hill has an elevation of 936 feet, or about 130 feet above the road and about 240 feet above the valley-train flats that bound the moraine on either side. An abandoned gravel pit can be seen on the slope of the kame to the northwest.

From here northward the elevation of the moraine gradually decreases except for several kames at the north end of the moraine that rise sharply above adjacent ground-moraine and valley-train deposits. Several of these kames appear to be partially buried, in fact, by outwash sediments lapping onto the lower slopes of the hills.

127.3 Partially descend the north end of the morainic tract, noting small kame on the right.

127.6 Turn right (east) at T-intersection and cross the northern tip of this small kame. From here several additional kames can be seen to the north, northeast, and east. Straight ahead is Money Hill, a 75-foot kame from which a considerable quantity of commerical gravel has been obtained. Abandoned gravel pits can be seen on both sides of the road where the kame is crossed 0.6 mile from the turn.

128.3 Turn left (north) at intersection 0.1 mile east of gravel pits and cross the east edge of Money Hill. The large hills ahead, known locally as McFarren Hill (to the west) and McCrea Hill (to the east), are also kames. McFarren Hill rises about 140 feet and McCrea Hill about 100 feet above the strip of outwash between them. The two kames probably merge at some unknown depth beneath the surface of the valley train.

129.1 Turn half right (northeast) at T-intersection near southern tip of McFarren Hill, proceed for 0.3 mile across outwash strip, and then turn half left (north). Continue 1.0 mile, crossing the east edge of McCrea Hill and descend directly onto the valley train along Big Blue River. The boundary between this terrace and ground moraine to the east (fig. 10) is subtle.

130.4 Turn left (west) at T-intersection and continue across valley-train deposits along Big Blue River. The kames to the south rise abruptly above the terrace level. Proceed for about 0.5 mile and then turn left (southwest) at T-junction onto winding road to Marietta, skirting edge of the floodplain along Big Blue River for 2.1 miles.

133.0 Turn right (northwest) in Marietta, descend onto floodplain, and cross the Big Blue River. This is the area of transitional boundary between the Muscatatuck Regional Slope and the Scottsburg Lowland, a boundary that here is little more than hypothetical. The influence of the Scottsburg Lowland upon the events of Pleistocene time was profound, however, as was demonstrated farther south. That influence is equally apparent in this area, as will be seen as we proceed westward across the lowland.

For the next several miles our route crosses a series of floodplain and outwash channels, including those of Big Blue River, Sugar Creek, and Youngs Creek. Individual valleys are hardly separable from each other, the several channels forming virtually a single sluiceway marked by elongate islands of ground moraine that rise only 10 to 20 feet above the floor of the valley (fig. 10). To the north these channels diverge; to the south they unite and are joined by that along Flatrock Creek to form one great sluiceway that carried meltwaters southward along the Scottsburg Lowland (fig. 10) and on through the gap in the Knobstone Escarpment south of Medora (fig. 5). Without question the confluence of Wisconsin meltwater streams in this zone was mainly controlled by the west edge of the East White Sublobe and by the relationship of the ice margin to the bedrock physiography.

Proceed northwestward 0.3 mile, and after crossing Big Blue River, proceed westward on its alluvium-veneered valley train for about 0.8 mile, turn left (south) at T-intersection near the nose of a ground-moraine island, and proceed 0.5 mile.

134.6 Turn right (west) with main road. The low rise about half a mile ahead is the east edge of a large island of ground moraine, about $4\frac{1}{2}$ miles long and $1\frac{1}{4}$ mile wide. Although its maximum relief is less than 25 feet, the island forms the divide between the drainage basins of Big Blue River and Sugar Creek. Cross the island and pass onto the valley train along Sugar Creek. The valley train is nearly $3\frac{1}{2}$ miles wide at this latitude, including a belt of thin alluvial deposits that overlie the outwash.

137.3 Turn left (south) and continue on valley-train deposits. The low knolls to the west are made of till and represent remnants of ground moraine that were not completely buried by the flood of outwash that poured into this zone during the retreat of the East White Sublobe about 19,000 years ago.

138.4 Turn right (west) at T-intersection. Alternately cross valley train and ground moraine, then descend onto floodplain, cross Sugar Creek, and continue on valley train 2.5 miles to U. S. Highway 31. Turn left (south) just west of highway onto old Highway 31 and proceed 0.5 mile.

141.4 Turn right (west) onto Indiana Highway 252, cross Youngs Creek, and ascend 70 feet to ground moraine on the younger Wisconsin (Cartersburg) till (fig. 10). The east edge of the till area is expressed topographically as a low north-south ridge that is about 20 feet higher than the general elevation of the plain to the west; the ridge is apparently composed of till, but its significance is unknown.

On the skyline ahead and to the southwest can be seen the broad sweep of the Knobstone Escarpment. The gradual decrease in the height of this escarpment from south to north is particularly noticeable.

145.0 Turn left (south) at Bethel Church onto county road.

145.3 STOP 6, Knobstone Escarpment. SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 10, T. 11 N., R. 4 E., Johnson County.

In striking contrast to the 300-foot escarpment that was observed earlier on the trip and its even greater relief near the Ohio River, the Knobstone Escarpment here is only about 60 feet high. A few miles farther north the identity of the escarpment as a topographic feature is lost entirely as the scarp passes beneath the thick drift cover of the Tipton Till Plain (back cover).

TIPTON TILL PLAIN: The nearly flat to gently rolling glacial plain that extends across the central third of Indiana is called the Tipton Till Plain (Malott, 1922, p. 104-112). For the past several miles our route has been generally parallel to, but just south of, the southern boundary of this plain, which here in eastern Indiana is probably the most obscure physiographic boundary in the State. It is placed arbitrarily at the north end of a broad transitional zone, in which the topography is similar to that of the till plain, but in which glacial drift is sufficiently thin for the general form of bedrock physiographic units to be recognized.

The nature of this transitional zone is exemplified well by the character of the landscape seen at Stop 6, which is perhaps 2 or 3 miles south of the arbitrary line along which the Tipton Till Plain truncates the Scottsburg Lowland and Norman Upland as recognizable surficial physiographic units. Below the thick drift of the central till plain, the latter continue along strike as bedrock physiographic units (Wayne, 1956).

Continue southward on county road.

146.2 The 40-foot hill to the west is an outlier of the Norman Upland protruding through the drift. In contrast to the generally larger and more numerous erosional remnants farther south, upland outliers here in the northern part of the Scottsburg Lowland are much smaller; many, of course, are completely buried beneath the northward-thickening blanket of glacial debris.

146.5 Turn right (west) and begin ascent of Knobstone Escarpment onto the Norman Upland 0.5 mile west of turn. Refraction seismic records indicate that the thickness of drift at this corner is about 110 feet.

Large glacial erratics, many of obvious granitic composition, are very abundant on both sides of the road at the base and along the face of the escarpment.

147.5 Turn right (north) and alternately cross spurs and valleys at the dissected east edge of the Norman Upland.

148.2 OBSERVATION POINT. SW corner $NW\frac{1}{4}$ $NW\frac{1}{4}$ sec. 15, T. 11N., R. 4 E., Johnson County. Stop briefly but remain in cars.

The skyline to the east, 10 to 11 miles distant, is the crest of the linear morainic segment that borders the east side of the Big Blue River valley train south of Marietta. The highest point, which is almost directly east, is the top of the massive kame viewed at Stop 5. Below this, about 4 miles to the east, is the crest of the low ridge at the east edge of the ground-moraine area.

The thickness of glacial drift draped over the Knobstone Escarpment in this area is not at all uniform. Seismic refraction shots a quarter of a mile north and three quarters of a mile south of here indicate 101 and 159 feet of drift. Yet on the next spur northward, green shale of the Borden Group can be seen at the base of the slope to the northeast, and siltstone is exposed on the west side of the road 0.6 mile north of here.

Proceed northward to Indiana Highway 252.

149.0 Turn left (west) at stop sign onto Indiana Highway 252. The route continues westward on Cartersburg till.

150.7 Cross Buckhart Creek.

Along the west bank of Buckhart Creek about 500 feet north of the highway is the section of Wisconsin drift designated by Wayne (1963, p. 45, 73) as the type section of his Trafalgar Formation (fig. 11). Present are both the upper or Cartersburg Till Member, which here is about 17 feet thick, and the underlying Center Grove Till Member, which is about 9 feet thick. The fossiliferous silt bed at the top of the Center Grove member is about a foot thick at this locality and contains wood that has an average radiocarbon date of 20,200 years B. P. According to Wayne (1965b, p. 38), the snail fauna collected from the silt reflects a change in environment from upland silt (loess) deposition to a floodplain environment. Wood from Center Grove till below the silt has yielded a radiocarbon date of 20,900 years B. P.

The following description of the Buckhart Creek section is modified from Wayne (1963, p. 73; 1965b, p. 39):

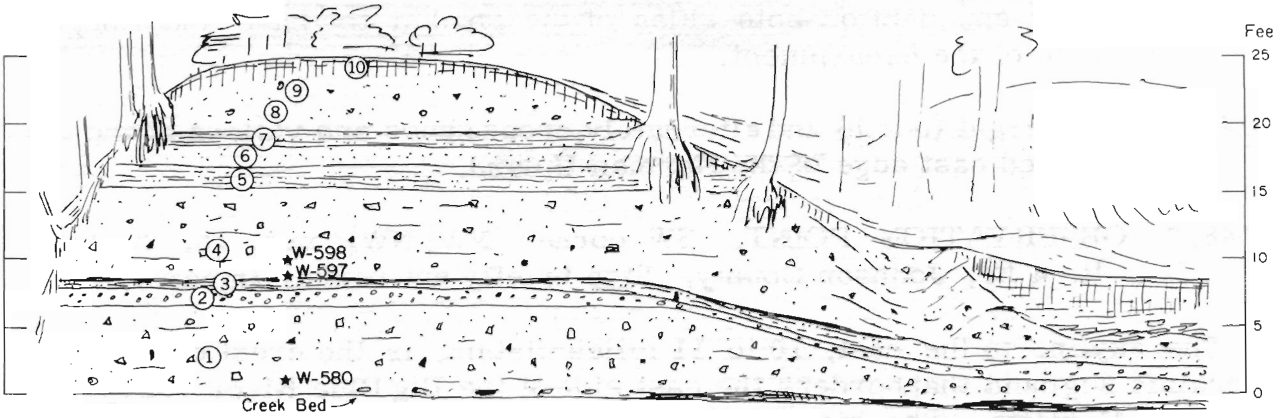

Figure 11. Sketch of Pleistocene section along west side of Buckhart Creek. Units are numbered in accord with detailed section description in text. Adapted from Wayne, 1965b, fig. 5-13.

	Thickness (ft)
Wisconsin Stage:	
Trafalgar Formation, 25.2 ft exposed:	
Cartersburg Till Member, 16.6 ft:	
10. Silt loam, light-gray	1.3
9. Till, pale-brown (10YR 6/3) between fractures, dark-brown (7.5YR 3/2) and clayey along fractures, noncalcareous	1.6
8. Till, silty and pebbly, pale-brown (10YR 6/3), calcareous; limonite deposits along horizontal partings	2.6
7. Silt, light olive-gray (5Y 6/2), porous, noncalcareous	1.0
6. Sand, clayey, dark-brown (10YR 4/3), noncalcareous	1.6
5. Silt, yellowish-brown (10YR 5/4), laminated, calcareous	1.6
4. Till, silty and pebbly, dark grayish-brown (2.5Y 4/2) in upper part, dark-gray (5Y 4/1) in lower part, calcareous, compact	6.9
Center Grove Till Member, 8.6 ft exposed:	
3. Silt, dark-gray (5Y 4/1) to dark-brown (10YR 3/3), fossiliferous; unit drops about 3 ft and becomes sandy at north end of exposure; C-14 dates of 20,100 ± 800 years B. P. (W-598) from top contact and 20,300 ± 800 years B. P. (W-597) from body of silt (*Vertigo alpestris oughtoni* bed)	1.0

	Thickness (ft)
Wisconsin Stage--Continued	
Trafalgar Formation--Continued	
Center Grove Till Member--Continued	
2. Gravel, sandy and silty, dark-brown (7.5YR 3/2), calcareous	1.0
1. Till, dark yellowish-brown (10YR 4/4) on face of exposure but dark-gray (5YR 4/1) on fresh surface, calcareous; lower part of bed contains contorted lenses of strong-brown (7.5YR 5/6) noncalcareous till and wood fragments dated as 20,900 ± 900 years B. P. (W-580)	6.6
Total thickness of section	25.2

On the east side of Buckhart Creek about 50 feet upstream from the main cut the Center Grove till overlies about 2 feet of strongly weathered Illinoian (Butlerville) till.

152.9 Turn right (north) at stop sign onto Indiana Highway 135, proceed for 0.3 mile, and then turn left (west) onto county road at west edge of the village of Trafalgar. About 0.7 mile ahead is a gentle 40-foot descent, which marks the west edge of the Cartersburg till. Descend from this unit onto the Center Grove till, turn left (south) at the T-intersection 0.8 mile farther west, and proceed 0.8 mile. At several points along this north-south road the topographic expression of the edge of the upper till sheet can be clearly seen. This rise is considered by Wayne (1965a) to be the front of the Crawfordsville Moraine in this area (fig. 8).

155.5 Turn right (southwest) at stop sign onto Indiana Highway 135 and 252, continuing on the Center Grove till to Morgantown.

160.3 Turn left (south), following Indiana 135 in Morgantown. About 2 miles south of Morgantown the Wisconsin glacial boundary is recrossed. The boundary is not defined in this area by any conspicuous physiographic feature but corresponds to the accumulation of drift mapped elsewhere in the State as the Shelbyville Moraine (fig. 8).

South of the Wisconsin boundary the route traverses an area that was glaciated during the Illinoian Age. The Illinoian drift is generally thin and patchy, however, and so the landscape differs only slightly from purely erosional topography on rocks of the Borden Group in the unglaciated part of the Norman Upland. Perhaps the most obvious effects of glaciation are anomalies in stream courses and partial derangement of drainage patterns. Thus the landscape is very similar to that seen earlier on the trip just west of the Knobstone Escarpment along U. S. Highway 50.

167.9 Junction with Indiana Highway 45 in Beanblossom. Brown County and adjoining Bartholomew County are sites of several other small towns with equally quaint names; nearby are Gnaw Bone, Stony Lonesome, and Stone Head. Continue ahead on Indiana 135 and cross the valley of Beanblossom Creek.

169.0 STOP 7, Beanblossom Overlook. SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 31, T. 10 N., R. 3 E., Brown County.

The valley of Beanblossom Creek marks the approximate limit of advance of both the Illinoian and Kansan ice sheets. In this area the Kansan ice actually advanced a bit farther than the Illinoian, as evidenced by exposures of probable Kansan till on the south side of the valley beyond the limit of Illinoian till and also by the presence of probable Kansan till beneath proglacial Illinoian lake sediments and Illinoian outwash at several places along the valley (Thornbury and Wayne, 1957; Wayne, 1958).

During Illinoian time Beanblossom valley was dammed by ice on both sides of the driftless upland (fig. 6): on the west side about 20 miles downstream from here, and on the east side about 2 miles from here, so that its upper end was diverted southward and now flows into the North Fork of Salt Creek. Illinoian lake clays are particularly well exposed 6 to 10 miles downstream (west), around the shore of Lake Lemon, an artificial lake from which the city of Bloomington obtains most of its water supply. During Wisconsin time the valley was again dammed, this time by outwash deposits of the valley train along White River (Thornbury and Wayne, 1957; Wayne, 1958, p. 12).

The horizon to the northwest is typical of the level skyline that can be seen almost everywhere throughout the Norman Upland. The nearly accordant summit levels at elevations of 900 to 1,000 feet are generally considered to be remnants of the Lexington or Highland Rim Peneplain, as interpreted by Malott (1922, p. 129-131, 173-174). A lower erosion surface is present along the major valleys of the Norman Upland and can be seen from here at several places across Beanblossom valley in the middle distance. One interpretation identifies this surface as a floodplain strath developed during the Lexington cycle, another as the product of a late Tertiary post-Lexington erosion cycle (Malott, 1922, p. 173-174), another simply as a stripped surface on resistant rocks within the Borden Group, and still another as a washed surface cut by glacial meltwater. At still lower elevations, about 40 feet above the stream bed, are silt-capped terrace remnants related to the damming of Beanblossom Creek during the Illinoian and Wisconsin glaciations.

Continue southward toward Nashville on Indiana Highway 135 through the unglaciated part of the Norman Upland.

The scenic beauty of this area has attracted many artists to the region, and Nashville is the site of numerous art colonies. These are particularly active during the colorful autumn season, when Nashville suddenly becomes the center of a booming tourist trade. Thousands of Hoosiers, and residents of nearby states as well, make an annual visit to Nashville and famous Brown County State Park to view the striking display of intense fall colors.

172.9 Nashville. End of first day.

Second Day

Mileage

0.0 Turn right (east) on Seventh Street from north entrance of the I. U. Memorial Union Building, in less than 0.1 mile angle right, and follow winding road through the campus to see additional examples of the use of Indiana Limestone.

0.3 On the left and opposite the southwest side of the Union Building is Maxwell Hall, which was built before 1900 in a purely traditional Romanesque style. Both rockfacing (chiseled at the construction site) and cut stone were used in the construction. An interesting feature is the hand-tooled fretwork on the trim of the main part of the building and on the turrets.

0.4 On the right (north), the Student Building has a sawed smooth finish in its upper part and in the clock tower, whereas the ground-level part is in solid stone rockfacing.

0.5 The Library Building on the right (north) is in Romanesque style and is constructed of solid stone rockfacing and cut-stone trim.

Bryan Hall on the left is in collegiate gothic style and is faced with variegated random ashlar and standard buff trim. The prominent rust staining of some stones was specified by the architect and was produced by placing iron shavings in the saw cut. The embedded particles later oxidized and imparted the rust coloring.

Continue straight ahead on Kirkwood Avenue, which becomes Indiana Highway 48. Continue westward on Highway 48 and cross the Mitchell Plain (p. 6).

4.6 Cross valley of intermittent stream that drains into a swallow hole about 2.5 miles downstream from the road. The closed drainage basin of the swallow hole is more than 4 square miles. Such enclosed basins containing small sinkholes are characteristic of large areas of the Mitchell Plain.

4.8 The hill to the right is part of a salient of the Crawford Upland and illustrates the irregularity of the upland's eastern margin.

CRAWFORD UPLAND: The Crawford Upland is a highly dissected elongate area containing a wide variety of landforms that have resulted from differential erosion of sandstones, shales, and limestones of late Mississippian and early Pennsylvanian age. This upland (back cover) is bounded on the east by the Mitchell Plain, and to the west it grades into rounded landforms of low relief on the Wabash Lowland, which was produced by erosion of Pennsylvanian rocks above the Mansfield Formation and by Pleistocene aggradation of many valleys. Thus the upland stands in marked contrast to the adjacent terrains, especially in southern Indiana counties near the Ohio River, where it exhibits some of the State's most rugged topography.

Although the eastern margin of the Crawford Upland is marked in places by a ragged dissected scarp referred to as the Chester escarpment (back cover), the boundary is not everywhere readily apparent. Hilly terrain is typical of the limestones along the western third of the Mitchell Plain adjacent to the upland, and outliers of Chester (upper Mississippian) rocks are common on the Mitchell Plain. Further, the karst topography of the plain extends into many valleys in the margin of the Crawford Upland where erosion has reached middle Mississippian limestones and is enlarging the limestone plain at the expense of the upland.

Topographic expression of the Crawford Upland includes sharp to flat-topped ridges of diverse form and structural plains of varying extent; canyon-like valleys, angular valleys having bedrock benches, deeply entrenched meanders, and flat-bottomed valleys; also caves, sinkholes, and associated natural bridges. Although most upland surface of even elevation is strongly bedrock controlled, remnants of the Lexington Peneplain are supposedly recognizable.

Along with the Norman Upland, the Crawford Upland was instrumental in diverting the Kansan and Illinoian ice sheets to the east and west of south-central Indiana, a circumstance that left an unglaciated reentrant in the ice fronts (fig. 6). A layer of upland loess a few feet thick is present in much of the unglaciated area. The northern and northwestern parts of the Crawford Upland were ice covered during Illinoian time, and the northern extremity was again ice covered during Wisconsin time. Illinoian drift is thin, and modification of landforms is minor, but topography north of the Wisconsin glacial boundary is greatly subdued.

5.7 Turn right (north) on secondary road, which here is in an enclosed drainage basin.

6.2 Road cut in Bethel Formation (Chester Series).

6.4 Road turns left, but continue straight ahead into quarry (mileage in quarry not figured).

STOP 1, Bloomington Crushed Stone Co. quarry. SW$\frac{1}{4}$ sec. 27 and NW$\frac{1}{4}$ sec. 34, T. 9 N., R. 2 W., Monroe County.

The ridge in which this quarry is located is part of a salient of the Crawford Upland projecting eastward into the Mitchell Plain. Shale and sandstone of the Bethel Formation were exposed at the top of the quarry, but the Bethel and the upper part of the underlying Paoli Limestone have been stripped away in the quarrying operation. The entire thickness of the Ste. Genevieve Limestone (middle and upper Mississippian) and the upper 8 feet of the underlying St. Louis Limestone are exposed in the quarry. (See fig. 2.) The quarry produces agricultural lime and crushed limestone and has a capacity of about 2,500 tons a day.

This stop supplements the first day's excursion by providing an opportunity to observe the upper part of the thick sequence of limestones underlying the Mitchell Plain. The following section is modified from descriptions made by personnel of the Industrial Minerals Section of the Indiana Geological Survey:

	Thickness (ft)
Mississippian System, more than 126.8 ft formerly exposed:	
Paoli Limestone, before removal, 18 ft:	
13. Upper part inaccessible for measurement and description.	
12. Shale, containing lenses and discontinuous beds of sandstone; sandstone, gray and brown, fine- to medium-grained	4.1
Ste. Genevieve Limestone, 100.8 ft:	
11. Limestone, gray, oolitic; top 0.5 to 1.0 ft brecciated (Bryantsville Breccia Bed)	10.7
10. Limestone, gray, mostly fine- to medium-grained; lower part is coarse grained and oolitic and has irregularly spaced shale partings	6.8
9. Limestone, gray to tan, lithographic and thin-bedded	5.0
8. Limestone, gray, fine- to medium-fragmental, including some oolitic zones, argillaceous in middle part	4.6
7. Shale, bluish-green, weathering to light-brown; a thin lower zone of calcareous sandstone is present in part of quarry; most of the weathering of this unit results from passage of ground water along its margins; position of unit marks the top of a pit cave 28 ft deep in the northwestern corner of the quarry, now completely quarried away	2.7
6. Limestone, gray, oolitic, arenaceous	3.0
5. Limestone, tan to gray, massive, micritic	28.0

	Thickness (ft)
Mississippian System--Continued	
Ste. Genevieve Limestone--Continued	
4. Limestone, gray, somewhat shaly, cherty	3.0
3. Limestone, gray, massive; shale partings common	23.0
2. Limestone, gray to brown, fine-grained, thin- to thick-bedded, cherty	14.0
St. Louis Limestone, 8.0 ft exposed:	
1. Limestone, gray to brown, fine-grained, thin- to thick-bedded, somewhat cherty	8.0
Total thickness of section (including Paoli)	126.8

The boundary between the St. Louis and Ste. Genevieve Limestones in this section is placed in accord with long usage in Indiana, but lithologic and faunal evidence from a recent study (Rexroad and Collinson, 1963) suggests that the boundary should be raised to the base of unit 7. A conodont-faunal break between the two formations has been recognized around the margin of the Illinois Basin, and only conodonts of type St. Louis age have been recovered from this quarry below unit 7.

Although Pennsylvanian rocks are not exposed here, the presence, before quarrying, of strata as young as early Chester contributes to understanding the Mississippian-Pennsylvanian unconformity (fig. 12).

MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY: The most pronounced and extensive break in the Paleozoic rocks of the Illinois Basin is found at the Mississippian-Pennsylvanian unconformity, which has a stratigraphic overlap of 1,850 feet in 200 miles. From south to north, basal Pennsylvanian strata truncate beds from the highest Mississippian rocks exposed in Indiana progressively downward through the oldest Mississippian onto the part of the New Albany Shale that is Devonian in age (Malott, 1951).

In Perry County on the Ohio River, the Mansfield Formation, which is the lowest Pennsylvanian formation in the State, overlies the Kinkaid Limestone (columnar section 1, fig. 12), the youngest exposed formation of the Chester Series in Indiana. Where Chester rocks are extensively exposed a short distance southwest of Bloomington, the upper ten formations of the series are not present, and the Golconda Limestone (Haney Limestone of Illinois usage) of the middle Chester is the highest formation (columnar section 4, fig. 12). The only Chester representatives seen along our route northwestward from Bloomington are the upper part of the Ste. Genevieve Limestone, the Paoli Limestone, the Bethel Formation, the Beech Creek Limestone, and sandstones of the West Baden Group.

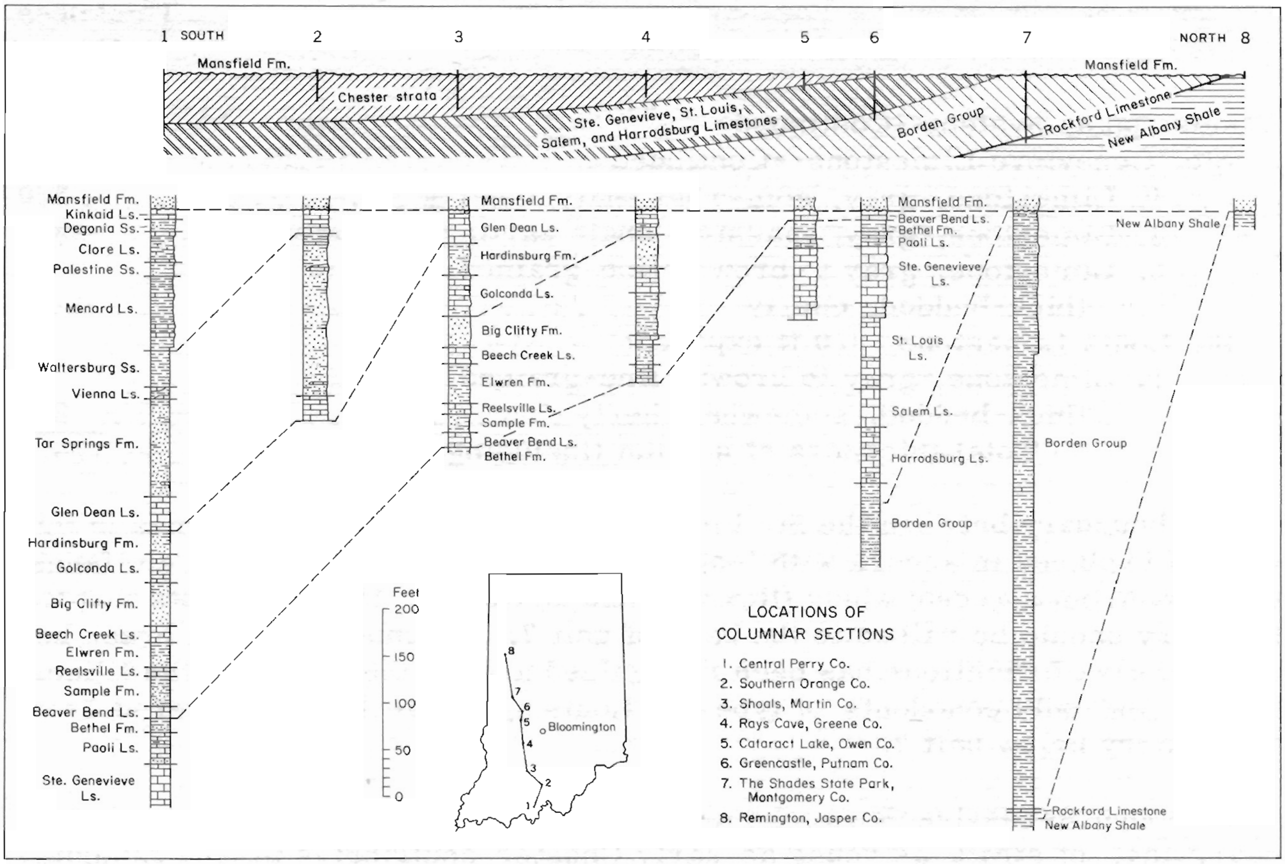

Figure 12. Cross section showing stratigraphic overlap of the Mansfield Formation in Indiana.

Although the unconformity generally increases in magnitude northward, local relief of 150 feet or more on a valley-and-ridge paleotopography permits local reversals in the direction of stratigraphic overlap. For example, at Greencastle in Putnam County the Pennsylvanian rests on and in channels in the Ste. Genevieve Limestone, but in the immediate area as much as 80 feet of younger beds, of Chester age, are present (columnar section 6, fig. 12). Farther north, in The Shades State Park in Montgomery County, basal Pennsylvanian rocks rest on shales of the Borden Group (columnar section 7, fig. 12 and fig. 14), and at the northernmost outcrop of the Pennsylvanian known in Indiana, two counties south of Lake Michigan, a Pennsylvanian outlier rests on the New Albany Shale. In addition to the north-south overlap, a similar east-west overlap of lesser prominence exists. Thus where the surface of unconformity approximately coincides with the present surface, complex relationships of outliers and inliers abound.

Lithologically the Mansfield Formation is very heterogenous, reflecting pre-Pennsylvanian tectonism and erosion as well as varied sedimentational history. Sandstones make up about three-fifths of the formation, thinly and somewhat evenly stratified sandstone being dominant over cross-stratified sandstone. Next in importance are fine clastic sediments, whereas coals (several of which have been named), sedimentary iron ores, and small quantities of limestone and chert are minor constituents. The sandstones include conglomeratic beds, particularly in the basal portions, and chert, milk quartz, geodes, coal, clay chips, and other materials also have been incorporated. Both plant remains and marine animals are represented by fossils in the Mansfield (Gray, 1962).

Leave quarry and retrace route southward on secondary road, repassing in 0.2 mile the Bethel exposure that was noted at mileage 6.2. Half a mile farther turn left (east) onto Indiana Highway 48, and turn left (north) in 0.5 mile at church; 1.2 miles to next entry.

8.8 Crest of small ridge of the upland salient. The higher, wooded hills of the Crawford Upland, their front marking the position of the Chester escarpment, can be seen to the left-front (west); 3.5 miles to next mileage entry.

Numerous small sinkholes are present along the road for the next half mile. The rather closely spaced newer houses built in this sinkhole area contribute to one of the water-supply problems common to the Mitchell Plain. Effluvia from septic tanks are channeled directly into the ground-water system with virtually no percolation, a condition resulting in much of the well water being contaminated. Only a few of the houses depend on cisterns.

12.3 Angle left (northwest) on Indiana Highway 46 and continue on highway through Ellettsville.

14.8 Turn left (west) onto Flatwoods Road. The road crosses part of the site of glacial Lake Flatwoods, a lake resulting from the ponding of preglacial drainage lines by an Illinoian ice front that formed an arc to the north and west. Lacustrine deposits cover an area of about 8 square miles. Lake Flatwoods drainage was through a gap to the south into a tributary of Raccoon Creek, which now has prominent terraces along its course. On the withdrawal of the ice, drainage for a time persisted south into Raccoon Creek because the old valley was effectively buried and dammed. Underground drainage was well developed, however, in pre-Illinoian time, and as the subterranean channels were cleared of debris, water once again followed the old subsurface channels. The underground predecessor of McCormicks Creek enlarged sufficiently to carry most of the drainage, and by weathering and erosion this line of drainage became a surface stream that now provides the main drainage of the Flatwoods (Malott, 1915).

16.1 For the next 0.4 mile the outlet of Lake Flatwoods and the divide between McCormicks Creek and Raccoon Creek drainage can be seen to the left-front.

16.5 Turn right (north) and in 2.0 miles turn left (west) onto Indiana Highway 46; 0.1 mile to next mileage entry. From here to the entrance to McCormicks Creek State Park (2.0 miles), the highway skirts approximately the northern shore of glacial Lake Flatwoods.

18.6 Road cut in the Ste. Genevieve Limestone.

19.1 Road cut through Bethel Formation and a small exposure of Paoli Limestone at west end of cut (both of Chester age).

20.1 Here the highway crosses McCormicks Creek upstream from the former subsurface course. In half a mile, near the intersection with Indiana Highway 43 and the entrance to McCormicks Creek State Park, the route crosses the margin of the Illinoian drift sheet and from there descends the east valley wall of the White River, which was a major Wisconsin sluiceway. Near the bottom of the east valley wall and 0.9 mile from the park entrance, the cut on the right (north) shows solution-collapse features in the St. Louis Limestone. A more normal section of the St. Louis Limestone is exposed 0.5 mile farther in a cut on the right (north).

Continue westward on Highway 46 through Spencer. Nearly white lithographic limestone of the Ste. Genevieve was used in the construction of several buildings in town.

24.3 The Clayton Winders and Sons quarry to the right (north) is operating in the Ste. Genevieve Limestone and has a capacity of 2,000 tons a day. The small abandoned quarry on the right in 0.8 mile includes beds of the Paoli Limestone as well as the Ste. Genevieve.

27.1 Slow down. Look to the right and back into a small draw where a few tons of rock was quarried from the Beech Creek Limestone. This is the youngest Chester formation to be seen on the trip. Northward, pre-Pennsylvanian erosion has removed progressively older strata. We are again in the Crawford Upland and will continue in it through the next stop. Although this area was glaciated during the Illinoian Age, drift has little effect on the landscape. Relief is not so great, however, nor terrain so rugged as in the Crawford Upland in southern Indiana.

is a second coal that has a maximum thickness of 3 feet. It rises and thins along the upper surface of the barlike sandstone where the latter thickens. This coal is overlain by fine-grained silty thin-bedded channel-form sandstone, which in turn is overlain by a similar sandstone.

Time discontinuities of any length during deposition of the sediments exposed here seem unlikely. Rather, lateral shifting of currents and of depositional environments apparently accounts for the relationships.

The upper part of the section, at the east end of the spillway, is probably the best known section of Pleistocene deposits in Indiana, having been examined during the course of several Pleistocene field trips, including a Friends of the Pleistocene (Midwest) excursion (Thornbury and Wayne, 1957) and Field Conference G held in conjunction with the VIIth Congress of INQUA (International Association for Quaternary Research) (Wayne, 1965b). The section was the first place in Indiana in which Kansan drift was recognized (Wayne, 1954, 1958). It has served as a type section for Pleistocene stratigraphic units (Wayne, 1958, 1963) and as a study site for the mineralogy of a Yarmouth soil profile (Bhattacharya, 1962) since the spillway was cut about a dozen years ago.

One striking aspect of this exposure is the sequence of glacial and interglacial climatic conditions that are represented and the clarity with which the climatic succession can be recognized. At the top of the cut (fig. 13) is exposed 3 feet of Wisconsin loess overlying about 23 feet of Illinoian till. The upper 12 feet of this till shows a well-developed weathering profile, which was formed during the interglacial Sangamon Age, but which has been partially modified by later (post-Wisconsin) weathering because of the relative thinness of the overlying loess. Beneath the fresh Illinoian till is about 27

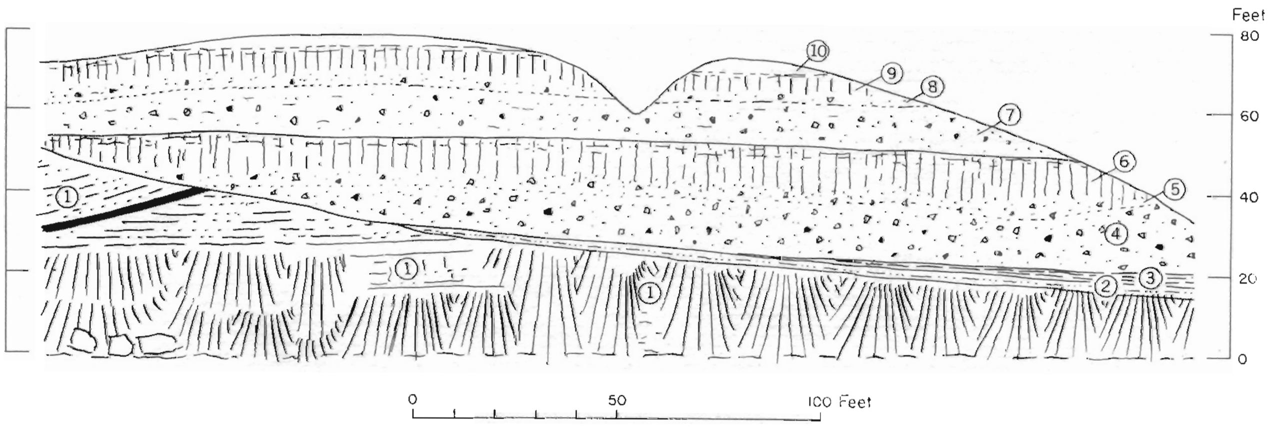

Figure 13. Sketch of Pleistocene section at emergency spillway of Cataract Lake. Units are numbered in accord with detailed section description in text. Adapted from Wayne, 1965b, fig. 4-11.

feet of Kansan till and clay, the upper part of which exhibits a weathering profile of Yarmouth age. The unaltered Kansan till is underlain by $2\frac{1}{2}$ feet of proglacial lake clay and this by 3 feet of fossiliferous loess, which rests on the Pennsylvanian rocks.

The following description of the section exposed at the east end of the spillway cut is modified from Wayne (1963, p. 71; 1965b, p. 35):

	Thickness (ft)
Wisconsin Stage, 3 ft:	
Atherton Formation:	
Peoria Loess Member:	
10. Silt, clayey, yellowish-brown, noncalcareous	3.0
Illinoian Stage, 23.3 ft:	
Jessup Formation:	
Butlerville Till Member:	
9. Till, brown, noncalcareous; secondary limonite deposits along joints	12.0
8. Till, clayey, light-brown, calcareous	5.3
7. Till, clayey, dark-gray, calcareous	6.0
Kansan Stage, 32.3 ft:	
Jessup Formation:	
Cloverdale Till Member:	
6. Clay, silty, sandy, brown to greenish-gray, noncalcareous	3.5
5. Till, silty, sandy, brown, noncalcareous	8.5
4. Till, silty, sandy, reddish-brown in upper part, brownish-gray below, calcareous; contains wood fragments in basal few feet	15.0
3. Clay, silty, brownish-gray, laminated, highly calcareous; contains scattered wood fragments throughout; unit is lenticular, pinching out toward west in exposure	2.3
Atherton Formation:	
Cagle Loess Member:	
2. Silt, grayish-brown, calcareous, fossiliferous; contains wood, peat, and humus along upper contact; unit is lenticular, pinching out toward west in exposure	3.0
Pennsylvanian System:	
Mansfield Formation:	
1. Sandstone, shale, and thin coals, overlain by as much as 12 ft of colluvial debris (not measured)	---
Total thickness of Pleistocene part of section	58.6

The nature of the Mississippian erosion surface upon which the Mansfield Formation was deposited (columnar section 6, fig. 12) is well shown by the channel in the Ste. Genevieve Limestone directly north across the lake. When the quarry was operating, this channel could be seen extending through the Ste. Genevieve into the top of the St. Louis Limestone. Much of the Pennsylvanian section is composed of dark shale, but pyritiferous sandstone containing plant impressions is found within the channels (Esarey, Bieberman, and Bieberman, 1950). The irregularity of the unconformity is further emphasized by the section in the Lone Star Cement Co. quarry $1\frac{1}{2}$ miles to the southwest. There Chester strata as high as the Beaver Bend Limestone were not removed by pre-Pennsylvanian erosion as they were at the observation point.

61.9 Turn right (north) onto Indiana Highway 231, and follow the highway through town. In 2.0 miles the road crosses a low glacial outwash terrace along the alluviated valley of Big Walnut Creek. The valley is uncommonly narrow at this place; 10.6 miles to Fincastle.

74.5 Fincastle. One mile to the west the Mansfield Formation rests on the Harrodsburg Limestone in a picturesque setting along Ramp Creek (Esarey, Bieberman, and Bieberman, 1950, p. 15). Here the Pennsylvanian rocks are channeled rather deeply into Mississippian rocks; the regional pattern of overlap (fig. 14) along the Mississippian-Pennsylvanian unconformity indicates that the St. Louis and Ste. Genevieve Limestones are the Mississippian formations expected at this latitude.

77.1 Turn left (west) onto Indiana Highway 236. In 1.1 miles the road is cut into a small alluvial terrace. Several cuts in the next mile expose Wisconsin drift; 2.8 miles to next entry.

82.0 Russellville Stone Co. quarry on left. The section from the top down includes about 20 feet of glacial drift; St. Louis Limestone, 23 feet; Salem Limestone, 10 feet; and Harrodsburg Limestone, 12 feet.

85.9 Turn right onto Indiana Highway 59. At the north edge of Waveland at the junction with Indiana Highway 47, Highway 59 ends (3.1 miles). Continue straight ahead (north) 3.0 miles on county road 750 West and turn left (west) onto Indiana Highway 234; 0.6 mile to next entry.

92.6 Slow down 0.6 mile past the junction of county road 750 West and Highway 234. The rise a quarter of a mile ahead is the front of the Champaign Moraine, which here trends in a general northeast-southwest direction (fig. 8).

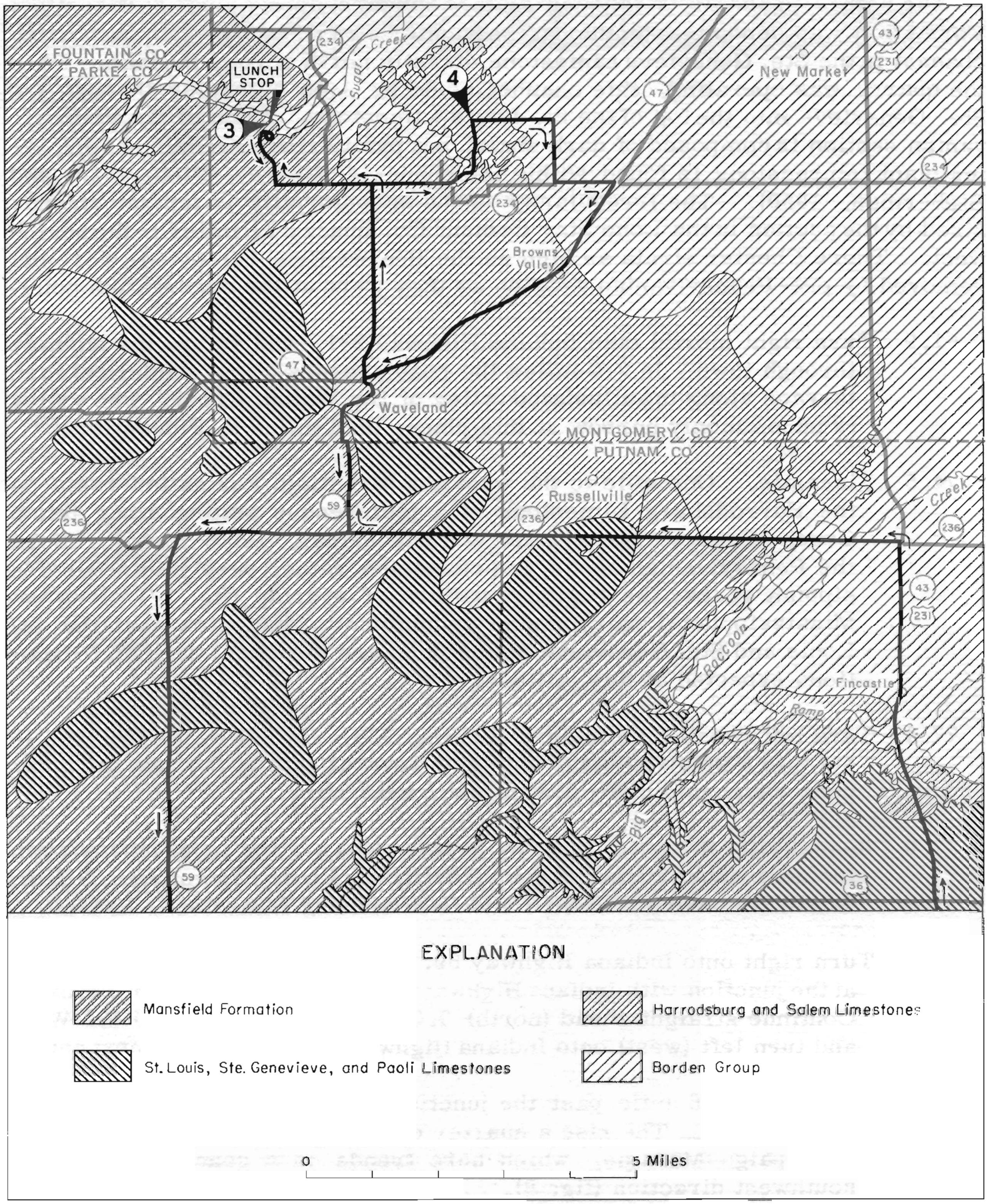

Figure 14. Map of part of west-central Indiana showing bedrock geology and route of AASG field trip. Modified from Wier and Gray, 1961.

The Champaign Moraine was formed as an end moraine of the Lake Michigan Lobe (fig. 7). The moraine extends into Indiana from Illinois, where it was named by Leverett (1899, p. 223-239), who traced it eastward across the State line and the Wabash River to this area. Our location, therefore, is on the west side of a reentrant angle between ice tongues that crossed different source areas and invaded the State from different directions--the Lake Michigan Lobe from the northwest and the East White Sublobe of the Ontario-Erie Lobe from the northeast (fig. 7).

The details of a complex history of ice advance and retreat in this area still may be questioned. A few miles north of here, at the apex of the reentrant angle, the Champaign Moraine merges with a northwest-southeastward-trending end moraine deposited at or near the margin of the Cartersburg till sheet (fig. 8). During the past 50 years and more the latter moraine generally has been considered to be correlative with the Champaign Moraine (Leverett and Taylor, 1915, p. 87-89), and the name Champaign consequently was carried southward around the marginal zone of the Cartersburg till. Recently, however, an earlier hypothesis of Leverett (1899, p. 224) was reasserted in part by Wayne (1965a, p. 11): that the Champaign Moraine was overridden by ice from the northeast when the East White Sublobe readvanced to a position marked by the edge of the Cartersburg till sheet. In this interpretation the name Champaign Moraine is restricted to the moraine on the west side (Lake Michigan Lobe side) of the reentrant angle, and the eastern moraine is now called the Crawfordsville Moraine (Wayne, 1965a).

92.8 Continue straight ahead on secondary road where Indiana Highway 234 turns right.

93.5 Turn right (north) onto secondary road and into The Shades State Park, proceed 0.3 mile to the gatehouse, and continue straight ahead 0.4 mile to Stop 3; pass the new parking lot, leaving blacktop for gravel road, and proceed to the picnic area.

94.2 STOP 3 and LUNCH STOP, The Shades State Park. NE$\frac{1}{4}$ sec. 10 and NW$\frac{1}{4}$ sec. 11, T. 17 N., R. 6 W., Montgomery County.

THE SHADES OF DEATH: One of the newest of Indiana's State parks, The Shades has a recreational tradition of more than a century. As one leaves the developed area and enters the virgin stands of beech, sugar maple, tulip poplar, oaks, and other hardwoods of upland broken by deep ravines and sandstone cliffs, he steps back more than a century to the wild grandeur that met explorers of the late 18th century who first paddled up the Wabash and thence up Pungosecome, the water of many sugar trees. A Federal land surveyor's report of 1812 identified, as a landmark, three mineral springs more recently named Youth, Beauty, and Health, which have enhanced the area's popularity.

From prehistoric time Indians made the springs a common meeting ground and camped and hunted in the area about them. Although the dark groves of hemlock lend a foreboding air, the pioneers' ingrained fear of the Indians lurking in the perpetual twilight of the nearly unbroken forest probably accounts for the early name of the area, The Shades of Death.

Here in The Shades are the most southerly groves of white pine in the State, which together with the hemlock are considered to be relics of subarctic vegetation that flourished in Indiana several thousand years ago. The rare American yew and wintergreen compete in a few places among the evergreens. Pines and hardwoods and their understory of redbud and dogwood give way along the streams to floodplain forests of sycamore, walnut, Kentucky coffeetree, cottonwood, and many others.

One of three log cabins near the springs dates back to the Civil War, when students from nearby Wabash College enjoyed outings in this still primitive area. Commercial exploitation began in 1886 when the Garland Dell Mineral Springs Association was formed, and it was this association that built the two-story frame hotel which still serves guests. In 1909 the association's stock was purchased by J. W. Frisz, who shortened the name to The Shades, and who sponsored a Chatauqua program featuring such notables as William Jennings Bryan, Carrie Nation, and Champ Clark. The Frisz family controlled the park until it decided to sell in 1947. Since the inception of the State Park system during the centennial year of 1916, the State of Indiana had had an eye on The Shades. Mr. Arthur Baxter bought and held the land until the State could raise the purchase price by subscription--pennies, nickels, and dimes from school children and individual gifts to $25,000. The original acquisition was 1,450 acres. In 1961 the additional 595 acres of the Pine Hills adjoining the original park on the east were added to the park as a gift of The Nature Conservancy. The Pine Hills and much of the remainder of the park will remain in the wild state--as it should.

GEOLOGY OF THE SHADES: Highlights of local geology can best be observed by following Trail 1, starting north of the concrete bridge over the Devil's Punchbowl, following the north edge of the ravine to the two overlooks 210 feet above Sugar Creek, descending a narrow gorge to the Devil's Kitchen at the base of the Mansfield sandstone cliff 55 feet below the overlooks, following the Mississippian-Pennsylvanian unconformity 155 feet above Sugar Creek, and ascending the gorge at spectacular Bridal Veil Falls to return to the bridge and starting point.

The drop of 210 feet from Prospect Point to Sugar Creek below is the result of erosion begun rather late in the Pleistocene Epoch, when this southwestward-flowing tributary to the Wabash River came into existence. Much of the stream's course probably was initiated along an ice margin, although some anomalies exist in this explanation. For example, here in The Shades, Sugar Creek crosses the crestal area of the Champaign Moraine, but the early high-level drainage along the ice front was to the south at the point of slowdown for viewing the margin of the moraine. It has been suggested in a similar situation (Wayne, in press) that crustal rebound from isostatic depression beneath the ice had not had time to occur immediately adjacent to the ice, but levels had risen a short distance away in areas vacated by the ice. Thus after the Lake Michigan Lobe had retreated as far north as The Shades and had stabilized temporarily, the surface immediately in front of the ice still was sufficiently depressed for the stream to take its present course, cutting across the crest of the moraine but following the temporary margin of the ice. Subsequently, the increased volume of meltwater pouring from the Ontario-Erie Lobe must have eroded so deeply as to establish firmly the course across the moraine.

As long as Lake Maumee (a precursor of Lake Erie) drainage was southwestward through the Wabash Valley, there was extensive downcutting of the major valley. A corresponding impetus was given to the tributaries as they adjusted, and this was a major erosional phase in the sculpture of Sugar Creek valley.

The stratigraphic relationships within the park complement the depth of erosion to provide the ruggedness of this limited area. The resistant sandstones of the Mansfield Formation have effectively prevented valley widening even though they are underlain by the relatively easily eroded shales and siltstones of the Borden Group (columnar section 7, fig. 12). The Chester strata and all the thick limestone units of middle Mississippian age are absent. This represents a stratigraphic overlap of more than 500 feet between Bloomington and The Shades.

Several miles upstream are biohermal masses in the Borden noted particularly for the richness of crinoid remains. Voluminous reports by Charles Wachsmuth and Frank Springer (1897) and other early paleontologists are based on collections from near Crawfordsville, and ecologic studies are currently being made by N. Gary Lane, University of California at Los Angeles. Only scattered exposures of this facies are found in the park: for example, a foot or so of crinoidal limestone where Trail 1 approaches Bridal Veil Falls and a thicker limestone at the base of the cliff near the bridge.

Return to park entrance and continue southward to T-intersection.

94.9 Turn left (east). Proceed eastward 0.6 mile to junction with Indiana Highway 234, recrossing the front of the Champaign Moraine, thence continue eastward on Highway 234 for almost 2 miles.

97.5 Leave Indiana Highway 234 where it turns right (south), taking left fork at the junction, and follow winding county road northeastward across Indian Creek and northward to T-intersection near Liberty School.

98.8 Turn right (east) at T-junction and stop.

STOP 4, Liberty School section. SW corner sec. 5, T. 17 N., R. 5 W., Montgomery County.

This section is somewhat similar to that seen at the emergency spillway of Cataract Lake, except that here we are north of the Wisconsin glacial boundary and Wisconsin till is intercalated between the Illinoian till and the Peoria loess. In addition, the soil developed at the top of the Illinoian till is a true paleosol, the Sangamon soil not having been modified by post-Wisconsin weathering and soil-forming processes as at the spillway cut.

Tills deposited during three of the four major glacial periods--the Kansan, Illinoian, and Wisconsin Ages--are exposed here, and three of the four interglacial ages--Yarmouth, Sangamon, and Recent--are represented by soils and weathering profiles. Despite its relative thinness, the section reveals one of the most complete records of major Pleistocene chronology anywhere in the United States. Consequently, it is another oft-visited locale, having been examined on the 1953 Biennial Pleistocene Field Conference (Thornbury and Wayne, 1953) and again on the 1965 INQUA trip (Wayne, 1965b).

The upper part of the section is more complete and better exposed on the north side of the east-west road; this exposure will be examined first, and then the main exposure on the west side of the creek across the north-south road will be studied. The following materials are exposed in the road cut (description of section modified from Wayne, 1965b, p. 34):

	Thickness (ft)
Wisconsin Stage, 13.5 ft:	
Atherton Formation:	
Peoria Loess Member:	
4. Silt, light yellowish-brown, noncalcareous; base somewhat uneven	3.3
Trafalgar Formation:	
Center Grove Till Member:	
3. Till, yellowish-brown (10YR 5/6 to 2.5Y 6/4), calcareous, stained by iron oxide along joints and bedding planes	6.6

	Thickness (ft)
Wisconsin Stage--Continued	
Atherton Formation:	
Farmdale Loess Member?:	
2. Silt, clayey, dark grayish-brown (2.5Y 4/2), slightly pebbly, noncalcareous; lower part contains MnO_2 concretionary masses	3.6
Illinoian Stage, 3.3 ft exposed:	
Jessup Formation:	
Butlerville Till Member:	
1. Till, sandy, strong-brown (7.5YR 5/6), noncalcareous; base not exposed	3.3
Total thickness of section	16.8

The main cut along the creek exposes the following section (description of section modified from Wayne, 1965b, p. 34):

	Thickness (ft)
Wisconsin Stage, 9.6 ft:	
Trafalgar Formation:	
Center Grove Till Member:	
11. Till, brown, noncalcareous	3.3
10. Till, sandy, silty, yellowish-brown (10YR 5/6), calcareous, compact	1.0
9. Till, silty, pebbly, yellowish-brown (10YR 5/6) in upper part, dark grayish-brown (2.5Y 4/2) in lower part, calcareous; lower part contains lenses of clayey coarse sand and fragments of wood	5.3
Illinoian Stage, 13.5 ft:	
Jessup Formation:	
Butlerville Till Member:	
8. Till, clayey, sandy, silty, mottled gray to strong-brown (7.5YR 5/8), noncalcareous	1.6
7. Sand, clayey and silty, gray to brown (varies from 10YR 6/2 to 10YR 5/3), noncalcareous; thickness irregular, as much as	1.0
6. Till, slightly clayey, strong-brown (7.5YR 5/8), noncalcareous; contains residues of nearly dissolved pebbles	0.3
5. Till, silty, sandy, brown (7.5YR 4/4), calcareous; base grades into unit below	3.0

	Thickness (ft)
Illinoian Stage--Continued	
Jessup Formation--Continued	
Butlerville Till Member--Continued	
4. Till, silty, sandy, very dark-gray (10YR 3/1), calcareous; lower 6 in. is brown	5.6
3. Thin interbedded layers of calcareous sand and till; sand is strong brown (7.5YR 5/6), till is yellowish brown (10YR 5/6); individual beds range from 10 to 20 in. in thickness	2.0
Yarmouth Stage, 6.3 ft:	
Prospect Formation:	
2. Silt and sand; silty parts very dark gray (10YR 3/1) to dark gray (10YR 4/1), loose to compact; paler and more silty near top; contains abundant wood fragments; stratified like alluvium; contains lenses of loose clean brownish-yellow (10YR 6/6) sand; top 4 in. of unit is calcareous	6.3
Kansan Stage, 2.6 ft exposed:	
Jessup Formation:	
Cloverdale Till Member:	
1. Till, very sandy, brown (10YR 4/3), very compact; base not exposed, but Borden siltstone occupies this position at the east end of cut	2.6
Total thickness of section	32.0

Travel east 1.2 miles on county road, turn right (south) at T-junction, continue 1.0 mile, turn left (east) onto Indiana Highway 234, proceed 0.9 mile, and turn right (southwest) onto Indiana Highway 47; 3.5 miles to next mileage entry.

For many miles the route traverses the lower (Center Grove) of the two Wisconsin till sheets in this area, and in this segment it is on ground moraine in the reentrant between the Crawfordsville Moraine (to the northeast) and the Champaign Moraine (to the west) (fig. 8).

105.4 Left bend in highway 1.7 miles southwest of Browns Valley. For the next several miles, the highway crosses the partly dissected (eastern slope of what has been considered for many years to be the Champaign Moraine. But here is additional evidence of the uncertainty of the Pleistocene record, for more recent interpretation places the distal margin of the moraine 3 or 4 miles farther west. Difficulty in recognition of landforms and in correlation arises in this area from several factors, including the overriding of one ice advance upon the position of another, interruption of morainal ridges by the Wabash valley train (among the largest in the Midwest), Recent submature dissection of the area accelerated by nearness to large Wabash tributaries, and influence of bedrock topography in areas of thin drift. Another factor is the presence of a loess cover over much of the morainal surface. The loess cap generally increases in thickness westward toward the Wabash Valley, whence it was derived from outwash sediments during late Wisconsin time.

Because of these and other factors, the physiography of parts of several counties in this area is not peculiarly characteristic of any one dominant set of geologic conditions. The rustic flavor imparted by the rugged, intricately arranged fingers of dissection encroaching upon the upland surface contrasts sharply with the aspect of prosperity of the rich agricultural uplands. Parke County, having its share of rustic heritage, sponsors an annual Covered Bridge Festival amidst the fall glory of hardwood forest and the largest number of covered bridges preserved in a single county of the State.

107.0 Waveland. Turn left (south) onto Indiana Highway 59 and proceed to Brazil. From Liberty School the route has crossed, along the bedrock surface, rocks of the Borden Group through the Harrodsburg and Salem Limestones (fig. 14). Immediately south of Waveland, near the Montgomery-Parke County line, the route passes almost at one point onto the St. Louis Limestone and the overlapping Mansfield Formation, this point at the slightly angular Mississippian-Pennsylvanian unconformity.

This unconformity is intersected over and over in this area by another profound, slightly angular unconformity--that at the base of Pleistocene and more recent sediments. Together with the related sedimentational complexities, especially in basal Pennsylvanian rocks, these unconformities lend fascinating character to this bit of Indiana geology (fig. 14).

114.9 About 3.5 miles north of Bellmore the highway passes from till that had been considered to represent the dissected end moraine (Champaign) onto ground-morainal till lying north of the southernmost Wisconsin end moraine (presumably the Shelbyville Moraine of the Tazewell Substage).

118.4 Bellmore and U. S. Highway 36 junction. Continuing on Indiana Highway 59, the route crosses the presumed Shelbyville Moraine (the oldest Wisconsin moraine of this area) in the next 3.5 miles.

121.8 About 2.5 miles north of Mansfield a drop of a very few tens of feet signifies the crossing of the Wisconsin glacial boundary and passing onto the partly dissected Illinoian plain, whose till is assigned to the Jessup Formation.

124.3 Mansfield, type locality of the Mansfield Formation. Interestingly enough, the oldest *described* Pennsylvanian marine faunas come, not from central or western locations in the Illinois Basin, but from Mansfield rocks along the eroded Pennsylvanian margin in Parke County and other areas in Indiana and southward into Kentucky (Thompson and Shaver, 1964). The pertinent fusulinid zones that have been recognized in conjunction with ostracod zones are those of pre-*Profusulinella* and *Profusulinella*.

135.5 Brazil, a coal-mining center and an acclaimed American clay capital. Turn right (west) onto U. S. Highway 40.

OF COAL MINING AND HISTORY: The history of coal mining near Brazil is a type example and, in its way, a mirror of mid-American history. (See Hutchison, 1960, p. 30-32.) The first mining of record, well more than a century old, is that of a stripping operation--by horse and scoop in the bluffs of Otter Creek north of town. Only a few decades later one could stand above the valley wall and count the smokestacks and tipples of 25 large, shallow underground mines within a 3-mile radius. These were in the Lower and Upper Block Coal Members (of the Brazil Formation, Pottsville Series), and shunting the loaded cars to the mainline of the Pennsylvania Railroad was a 24-hour job.

The smoke had disappeared from Otter Creek by 1900, but many new stacks could be counted at deeper 250-foot underground mines in the same coal beds a few miles northwest of Brazil. The new smoke, too, had nearly disappeared a quarter of a century later and was giving way to the new machines that laid the black seams bare from the surface downward. The availability of new fuels, oil and gas, also began to have its effect, although the coal-mining industry, even while declining, retained some vigor as still larger stripping equipment was brought in and the underclays were found to be valuable. Eventually the associated clays assumed the dominant role, so that in recent years a dozen plants at Brazil have been manufacturing products ranging from ordinary ceramic materials to the very finest glazed structural tile.

Significant reserves of coal remain near Brazil, but they compete poorly in today's market for great tonnages used for electric power generation--this partly because the fusion point of Block coal ash is too high. The proper use of these reserves constitutes a challenge for the future.

139.1 Turn left (south) onto blacktop road to Staunton, pass through the Pennsylvania Railroad overpass, and enter an area of intensive coal mining where details of Pennsylvanian stratigraphy and some of the most modern equipment and methods of land reclamation may be observed.

139.6 On the right (west) side of the road the sign "Lakellar" proclaims the area as a private home constructed on a strip-mine lake and amid pine and spruce trees that were planted in the abandoned mined area. Permanent and summer homes on lakes in abandoned but reclaimed strip mines are common in this area. South along the route are pine trees planted on both sides of the road in abandoned strip mines.

140.2 Curve right (west) and then left past Staunton School and continue southward through the middle of Staunton. The Staunton Formation (Allegheny Series), which contains the Seelyville Coal Member (III) (usage proposed by Wier, in preparation) and 150 feet of older rocks, takes its name from exposures near this town.

141.4 Take right fork in road just beyond where blacktop ends, and pass abandoned strip mines on both sides of road. Black fill on left is fine-sized refuse from preparation plant that was pumped into a so-called last cut.

141.9 Leveled area on the left where road curves right and then left. Here more than 200 acres that were stripped and leveled are now farmed by Meadowlark Farms, Inc., a subsidiary of Ayrshire Collieries Corp.

143.2 Turn left (east) onto Ayrshire's haulage road, and in 0.4 mile turn right into active pit of the Chinook Mine.

143.6 STOP 5, Chinook Mine, Ayrshire Collieries Corp. Secs. 27 and 28, T. 12 N., R. 7 W., Clay County.

Chinook Mine and Land Reclamation
By Charles E. Wier

The Chinook Mine, Ayrshire Collieries Corp., has been mining the Seelyville Coal Member (III) at the top of the Staunton Formation here in western Clay County for 25 years. This stripping operation removes as much as 90 feet of overburden to reach 6 feet of coal. In much of the area the upper half of the overburden is unconsolidated till of Illinoian age and the lower half is sandstone, siltstone, and shale of Pennsylvanian age. In part of the area one or two other coal beds and a limestone bed also are present above the mined coal. Good exposures of Pennsylvanian rocks in the Staunton and Linton Formations (Allegheny Series) are present in the active cut.

At the time this guidebook was prepared the rocks were not exposed in the 160-acre area (approximate) where the dragline is now working. Driller's records of 11 coal tests in this area were obtained from Ayrshire Collieries Corp. The range in thickness of the rock units is summarized below. Depth to the mined coal, and thus the height of overburden, ranges from 60 feet, where the older equipment quit mining, to more than 90 feet, under the highest part of the hill. All the rock units vary laterally and vertically, but the most noticeable variation is in the interval between the Seelyville and Colchester Coal Members. Where sandstone is not present this interval contains as little as 15 feet of gray shale and sandy shale, but where a thick sheet sand is present the interval may be as much as 55 feet.

The following section summarizes drilling data in the W$\frac{1}{2}$ sec. 27 and the E$\frac{1}{2}$ sec. 28, T. 12 N., R. 7 W., Clay County:

	Range in thickness (ft)
Quaternary System:	
Pleistocene Series:	
Illinoian Stage (Jessup Formation, Butlerville Till Member):	
1. Till; contains weathered till and a thin veneer of weathered loess at the surface	13 to 24
Pennsylvanian System:	
Carbondale Group:	
Linton Formation:	
2. Shale, gray and sandstone, fine-grained	10 to 36
3. Shale, black; in places contains a dark impure limestone band less than a foot thick	3 to 22
4. Coal, bright-banded; Colchester Coal Member (IIIa)	0.7 to 2.5
5. Underclay, light-gray	2 to 7
6. Shale, gray	0 to 6
7. Sandstone, light-gray, fine-grained	1 to 40
8. Shale, gray	0 to 7
Staunton Formation:	
9. Coal, bright-banded; contains pyrite in thin horizontal bands and paper-thin films in vertical cleats; in places a shale and pyrite parting as much as a half a foot thick is present near the middle of the seam; Seelyville Coal Member (III)	4.7 to 6.7

The Chinook Mine is typical of modern coal-producing stripping operations in the Midwest. It has a combination of both old and new equipment that is modified and adjusted to make a smooth-running efficient operation. Some equipment is 25 years old, the 40-cubic yard stripping shovel is 13 years old, and the large dragline is less than a year old.

This dragline, known as the Bucyrus Erie model 2550-W dragline, was assembled during a 10-month period ending in January 1966. Its bucket has a 75-cubic yard capacity (nearly 112 tons of rock), its boom is 275 feet long, it weighs 4,500 tons, its highest part is about 153 feet above the ground, it can dig as deep as 165 feet below its base, and it operates on 6,900 volts of 3-phase 60-cycle electricity that is purchased from the Public Service Co. of Indiana. Although this dragline cost more than $6 million, Ayrshire expects that the dragline, because of its larger capacity and increased efficiency, not only will remove a greater depth of overburden at decreased cost per cubic yard but also will allow the company to mine coal that otherwise would have been too deep. This and the other strip mines in Indiana produced about 12½ million tons of coal last year (more than three-fourths of the State's production).

Ayrshire has produced more than 16 million tons of coal at this mine during the past 25 years, and, with the new equipment, it expects to produce a similar amount during the next 11 years. A small amount of coal has been produced from the Survant Coal Member (IV) (usage proposed by Wier, in preparation), but nearly all this production came from the Seelyville Coal Member (III). In the area where the new dragline will be working during the next several years, this coal averages 90 feet deep, is about 6 feet thick, is high-volatile bituminous coal, and as raw mine-run coal it contains 6 to 18 percent ash and 3 to 5 percent sulfur on an as-received basis.

After the overburden has been removed, 50 tons of coal is loaded into each truck by a loading shovel that has a dipper capacity of 8 cubic yards (6 tons of coal per bite). The company plans to buy a new loading shovel having a capacity of 10 cubic yards. The trucks travel over company-owned haulage roads to a preparation plant, where the coal is cleaned and prepared to specifications of the customer and the percentage of ash is reduced to 9 percent and sulfur to less than 3 percent. Electric utility companies consumed 67 percent of the production last year, and, in fact, they consumed nearly two-thirds of the State's total coal production in 1965.

After the coal has been removed from the ground, Indiana State law requires that the land be reclaimed in such a manner that the value of the land will be enhanced; that soil erosion, hazards of floods, and the pollution of water will be reduced; and that, where possible, wildlife will be encouraged and protected. Normally this means constructing earth dams in final cuts to impound the water, knocking the tops off the strip-mine ridges and peaks, and planting the area in trees. Seedlings are planted at a density of about 700 per acre. Conifers are commonly used, but hardwoods are planted where the pH of the strip-mine spoil is high enough.

In the area of the Chinook Mine the Illinoian till is thick and calcareous. In the spoil area the till tends to neutralize the more acidic shale and sandstone, and thus the spoil is nearly neutral. In previous years the 40-cubic yard stripping shovel could not handle the volume of overburden and maintain the proper width of cut. It was assisted by a 9-cubic yard dragline that, in rehandling spoil, was able to level it. This combination of neutral soil and leveling allows much of the stripped area to be used for agriculture. A subsidiary company, Meadowlark Farms, Inc., manages 19,000 acres of reclaimed land in Indiana, Kentucky, and Illinois, including 5,000 acres at the Chinook Mine. The land is used for grazing, cultivation of crops, and recreation. Alfalfa is grown and beef cattle graze on reclaimed strip-mined land at Chinook. Trees planted here include locust, scotch, jack, and Virginia pine, chestnut, walnut, pecan, oak, maple, cottonwood, sycamore, and European alder.

Probably the first strip-mine reclamation project in the United States was nearby in Clay County, where in 1918 several acres of spoil were planted in fruit trees. Some of these still bear fruit. As early as 1926 member companies of the Indiana Coal Producers Association began a voluntary but limited reclamation program, but before the State's reclamation law was passed in 1941 most of the strip-mined area was simply abandoned. Since 1941, however, nearly all the approximately 2,000 acres stripped each year in Indiana have been reclaimed. Some reclamation work is minimal and leaves much to be desired.

About 75 percent of the 85,000 acres disturbed by strip mining of coal in Indiana has been planted in trees. Only 2 percent of the stripped area has been graded and seeded and is now used as farms. Another 6 percent has been seeded but not graded. Because more than 10 percent of the strip-mined area is left as lakes, some areas are ideal for recreational development. One of these areas is Dietz Lake on the south side of Indiana Highway 46 along the return route to Bloomington. This lake has been privately developed into one of the most popular resorts in southwestern Indiana. It covers 200 acres of reclaimed strip-mined land and offers facilities for bathing, boating, fishing, and camping.

About 30 miles to the south, Greene-Sullivan State Forest contains 5,488 acres of mined land that was planted in trees by the coal companies and donated to the State. Another 35 miles south is the Patoka State Fish and Game Area that contains 4,000 acres of reclaimed strip-mined land. Here the coal companies leased the land to the Indiana Department of Natural Resources and continue to pay taxes on the land and to manage the timber. The Department of Natural Resources stocked the lakes with bass, bluegill, and crappie and is developing an upland game-hunting area. Many people who work in cities, such as Terre Haute and Brazil, live in homes that are built on reclaimed strip-mined land and are adjacent to a well-stocked lake. Many more people have cottages or summer homes adjacent to these lakes. The facilities mentioned are only a small part of the recreational facilities that have been developed or are now being planned to use what was formerly called waste land.

The operators of surface coal mines have a large amount of money invested in the land that they plan to mine, and they know that they will continue to pay taxes on the land after the coal has been mined. Following normal sound business practices, they now try to bring this land to its maximum value and usefulness as soon as possible after mining has ended. In some places, even before mining is started in the area the company plans how best to use the land after the coal has been removed and the huge mining machinery has moved on.

For Indianapolis interchanges, retrace route 4.5 miles to U. S. Highway 40, turn right (east) onto highway, and proceed about 53 miles.

For Terre Haute junctions or Bloomington, retrace route west 0.4 mile, turn left (south) onto county road, and proceed 0.4 mile to Indiana Highway 42. Turn right (west) for Terre Haute, about 10 miles. Turn left (east) for Bloomington, proceed 4.0 miles, turn right (south) onto Indiana Highway 59, turn left (east) in about 5 miles onto Indiana Highway 46, and proceed about 36 miles.

The Salem Limestone as Dimension Stone[1]

By Lawrence F. Rooney

Stone is romantic. It is what castles are made of, the stuff of history. Past civilizations wrote their records boldly in temples, pyramids, and cathedrals, and through the rise and fall of empires some men have always lived in caves. If our civilization must decline, perhaps through a trajectory mirroring its ascent, one day stone castles may grace the banks of the Ohio and stone fortresses dominate the Knobstone Escarpment.

But time and uncertainty make it unwise for the dimension-stone industry to attend that day of maximum exploitation. Instead, it must serve the need of the 20th century, an era of corporations and public spending rather than of castles and private wealth. Since the late 1800's, largely through exploitation of the Salem Limestone (fig. 2), Indiana has been able to serve that need well. Inobtrusive in appearance, often mistaken for concrete, the Salem (also known commercially as Indiana Limestone) excels in its amenability to quarrying and fabricating. This amenability depends in turn on the stone's physical characteristics: thickness, texture, and stratification, determined longer ago than most of us care to remember.

GEOLOGY: Some 300 million years ago the comminuted shell fragments and microfossils that compose the Salem Limestone were deposited along the margins of a shallow sea covering most or all of Indiana. For a modern parallel one might examine the sand now being deposited along the coast of Florida. At Ormond Beach, the sand is composed of coarse shell fragments, many of them almost whole; at Miami Beach, some 250 miles farther south, the sand is composed of finer shell fragments. Similarly, the seas that covered Indiana deposited whole microfossils and shell fragments of one size in one area, another size in another. The sea margins migrated landward or seaward with time, and deposition of this carbonate sand was interrupted in some areas by influxes of mud. Lagoons impeded circulation and caused local concentration of unoxidized matter. As a result, a geometrically complex network of lenticular bodies of skeletal debris was cemented into a wedge of rock identifiable over south-central Indiana and adjacent states as the Salem Limestone. Only part of the Salem is suitable for use as dimension stone and only a small part of that stone has been exposed by uplift and erosion. Thus exploration for new deposits is not simply a matter of locating a thick wedge of the Salem Limestone. It is a matter of locating a pod of suitable stone within that wedge.

The Salem Limestone crops out from Montgomery County to the Ohio River (fig. 15) and beyond into Kentucky, but the thickest units of dimension-stone

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[1] Reprinted in part from the Indiana Business Review, September 1965, with the permission of the Indiana University Graduate School of Business.

quality are found in Monroe and Lawrence Counties, where all current production is centered. Dimension stone has also been quarried in significant amounts from both Owen and Washington Counties, which remain potential areas for new quarries. Although the formation is in places more than 80 feet thick, most quarries contain less than 60 feet of usable stone.

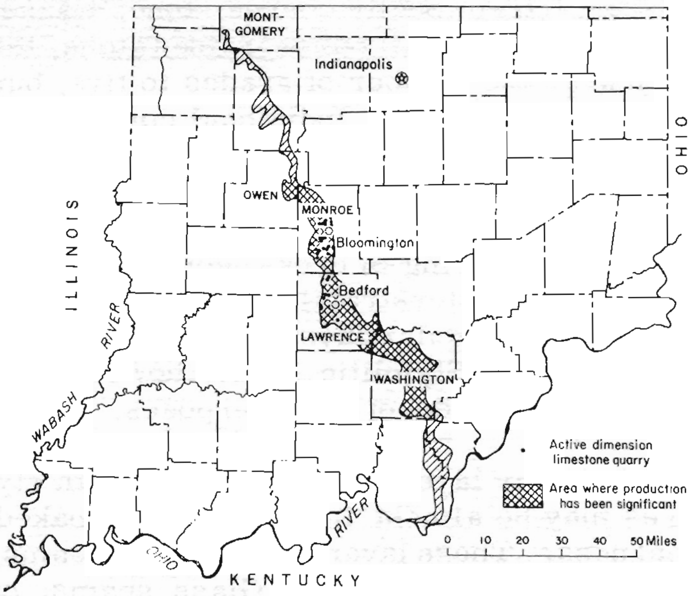

Figure 15. Map showing area of significant dimension-stone production within the outcrop belt of the Salem Limestone.

An outcrop of the Salem Limestone is relatively easy to identify by its massive rounded ledges, gray color, and coarse texture, all of which remind one of an elephant's hide. Chemically it is almost pure calcium carbonate (98 percent) and is composed of a diverse assortment of fossils and fossil fragments, as much as several centimeters in length but generally about 0.7 mm in average diameter. A common microfossil, *Endothyra baileyi*, spheroidal in shape, gave rise to a misnomer, oolitic limestone, now municipally enshrined as Oolitic, Ind.

BUILDING STONE PROPERTIES: The number of different stone products marketed (generally as Indiana Limestone) may appear large and confusing because several independent qualities are involved: color, texture, and milling.

The colors of Salem limestone are various shades of buff and gray, or a mixture of the two. Although dominantly calcium carbonate, the Salem contains a number of trace constituents, such as organic matter and pyrite, which in the unoxidized state give the stone a gray color, and in the oxidized state, a buff color. Because oxidation occurs when the stone is exposed to the air or to oxygenated ground water, gray stone turns buff where it has been above the water table for a sufficient length of time. Variegated stone is found both at the water table and along fractures and solution channels, which have permitted the rapid percolation of ground water below the water table.

Most Salem dimension stone falls into three textural grades: rustic, standard, and select. These categories are based primarily on the size of the pores. In rustic stone the pores may be greater than 2 mm in diameter; in standard they may be as much as 2 mm; in select they should be less than 1 mm. Grade also corresponds to a decrease in grain size from rustic to select. Exceptionally coarse stone, termed gothic by members of the industry, and exceptionally fine-grained stone, termed statuary, might be considered to enlarge the number of grades to five, but the total output of gothic and statuary stone is small. Individual companies may give trade names, often with exotic connotation, to varieties of these five grades.

Stylolites, called crow's feet by the industry, are considered a textural defect. Appearing in cross section like a Dow-Jones graph, stylolites are the result of the interstratal solution of limestone and accumulation of residual clay along irregular layers. Under tensional stress, they also may be planes of weakness. Stylolitic stone, however, is attractive, especially in ashlar, and is used for decorative purposes.

Some clay layers not associated with stylolites and some unannealed fractures may be almost invisible to the naked eye, but they are also planes of weakness. These layers, called dry seams, cause the waste of what otherwise appears to be good stone. Glass seams, on the other hand, are vein fillings of coarsely crystalline calcite and do not necessarily decrease the strength of the rock. They are also considered a defect, however, because they detract from the uniform appearance of the stone. Much stone that cannot be used for dimension stone is simply called bastard stone. Most of it is dark, fine grained, tightly cemented, slightly argillaceous, silty, or dolomitic.

Ironically, the industry's emphasis on homogeneity of texture and color has been both a blessing and a curse. Before the appearance of portland cement at about the turn of this century, Salem limestone probably was this country's cheapest durable building material that was homogeneous in both color and texture. It remains one of the most uniformly textured stones on the market. Portland cement, however, named for its resemblance to the famed Portland dimension limestone of England (but which resembles Salem limestone equally well) can be manufactured to achieve even greater color and textural homogeneity. Keen competition between cement and Salem limestone was inevitable and continues to this day.

Classification and pricing by the Indiana industry itself have perpetuated the emphasis on homogeneity and color. The most homogeneous, finest-grained buff stone demands the highest price, and variegated, nonuniformly textured stone the lowest. Residence veneer, estimated at less than 20 percent of the total market, cannot absorb all the stone rejected as cut stone. As a result of many factors--high specifications; the real and supposed defects of crow's feet, dry seams, and glass seams; rock overburden; bastard stone; and the normal waste of quarrying and milling--more than 50 percent of quarried stone is wasted.

With only minor exceptions, Salem limestone used as dimension stone is cut stone. Only if it is ready to be set in place on the job, however, is it described as such. In the past, channelers--steam, gasoline, or electrically driven chisels mounted on tracks--were used almost exclusively to cut the blocks out of bedrock. Although still used, especially to remove the key blocks, they have largely been replaced by wire saws, which are more economical to operate. After a hole has been opened, great slabs averaging 60 feet long, 4 feet wide, and 8 to 12 feet high are cut from the quarry face, toppled onto their sides with cables attached to standing derricks, cut into several blocks, and shipped to mills where gang saws, resembling toothless crosscuts, slice the block into a dozen or so slabs. The slabs in turn may be planed and cut into sills, coping, panels, or the rectangular veneer called ashlar seen on many residences. Some of the blocks, of course, are cut into more special shapes required for ornamental buildings. Few pieces of cut stone match the size of the 100 one-piece columns, 36 feet long and 6 feet in diameter, which were turned out on a lathe for the Mellon Memorial Library in Pittsburgh. Many thousands of pieces, however, do exceed them in complexity of design.

Two major advantages of Salem over most other building stone are its softness and its lack of pronounced rift or grain, which permit it to be carved in fine detail. In fact, the golden age of Indiana's stone industry was reached late in the Victorian epoch and climaxed during the Roaring Twenties, a most propitious period for stone amenable to intricate design. In the past few decades, architects have emphasized simplicity and functional design, but a return to ornamental carving is as inevitable as change in women's fashions.

PRODUCTION: Although Indiana produces more than 60 percent of the dimension limestone quarried in the United States, dimension limestone accounts for only 5 percent of the State's total mineral output. Nevertheless, since 1877 approximately 52 million tons has been produced with a value in 1963 dollars of more than $1.5 billion.[2]

Peak production was reached between 1920 and 1930, before mineral statistics were regularly reported in any detail. Even now, production statistics are unreliable because some stone is sold once as block or sawed stone and then is sold a second time as cut stone. The value is probably greater than $1.5 billion because the production reported to the U. S. Bureau of Mines is only that of the primary producing companies and not the independent fabricators.

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[2] The figure is based on an assumed average value of $30 per ton. Pre-1940 production figures were compiled from J. A. Batchelor, "The Indiana Limestone Industry," Bloomington, Bureau of Business Research, Indiana University, 1944. Post-1940 figures are from U. S. Bureau of Mines Minerals Yearbooks, Washington, U. S. Govt. Printing Office, 1941-64.

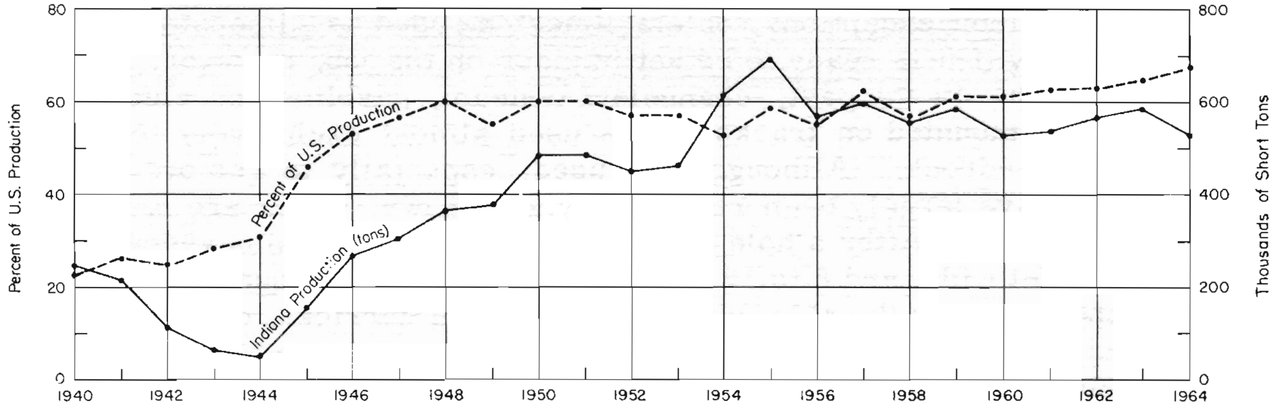

Figure 16. Graph showing production of dimension limestone in Indiana. Data from U. S. Bureau of Mines Minerals Yearbooks.

The major market for Salem limestone lies within 200 miles of a line drawn from Chicago to New York. Most of the stone is used in Indiana and adjacent states. In the past, however, a larger proportion was shipped to the eastern seaboard, especially the New York and Washington, D. C., areas. The relative drop in sales is largely due to the popularity of synthetic veneers, such as concrete, steel, and glass.

After World War II, production climbed fairly steadily to 1955 and has since leveled off at about 600,000 tons per year (fig. 16). The industry has made a vigorous effort to increase its efficiency and to unite in promotional efforts. For example, the proportion of wire saws used in the quarries has increased; a new source of abrasive sand has been found in southern Indiana; diamond gang saws have reduced the time required to saw a quarry block by as much as 75 percent; and mobile cranes are replacing some of the stationary derricks. In short, emphasis is being placed on finding new ways to do the job better.

Promotional efforts have met with less success. An organization called the Indiana Limestone Institute was formed in 1928 to establish standards and encourage the use of Salem limestone. The good work accomplished by this institute included the publication of a valuable handbook. The institute failed to maintain the support of the industry, however, and disbanded in 1963. In the same year, the National Association for Indiana Limestone, Inc., which emphasized promotion rather than research, was formed, but it disbanded in 1964. During that year, the Indiana Limestone Institute of America, Inc., was formed, with D. R. Bliss as executive director. This organization has wide support, and it is hoped it will carry on successfully the work begun by the Indiana Limestone Institute.

Despite its chronic difficulty in speaking with one voice, the dimension-limestone industry of Indiana is basically healthy. Reserves of stone will last indefinitely. Competition from synthetic and other natural products will continue to be vigorous: Synthetic products, of which concrete is paramount, will dominate that part of the market where price and utilitarian values are of first consideration. Other natural stones, such as marble and granite, will offer considerable competition where price is immaterial. But where aesthetic values are important and cost must be considered, Salem limestone will remain the premier dimension limestone of the country.

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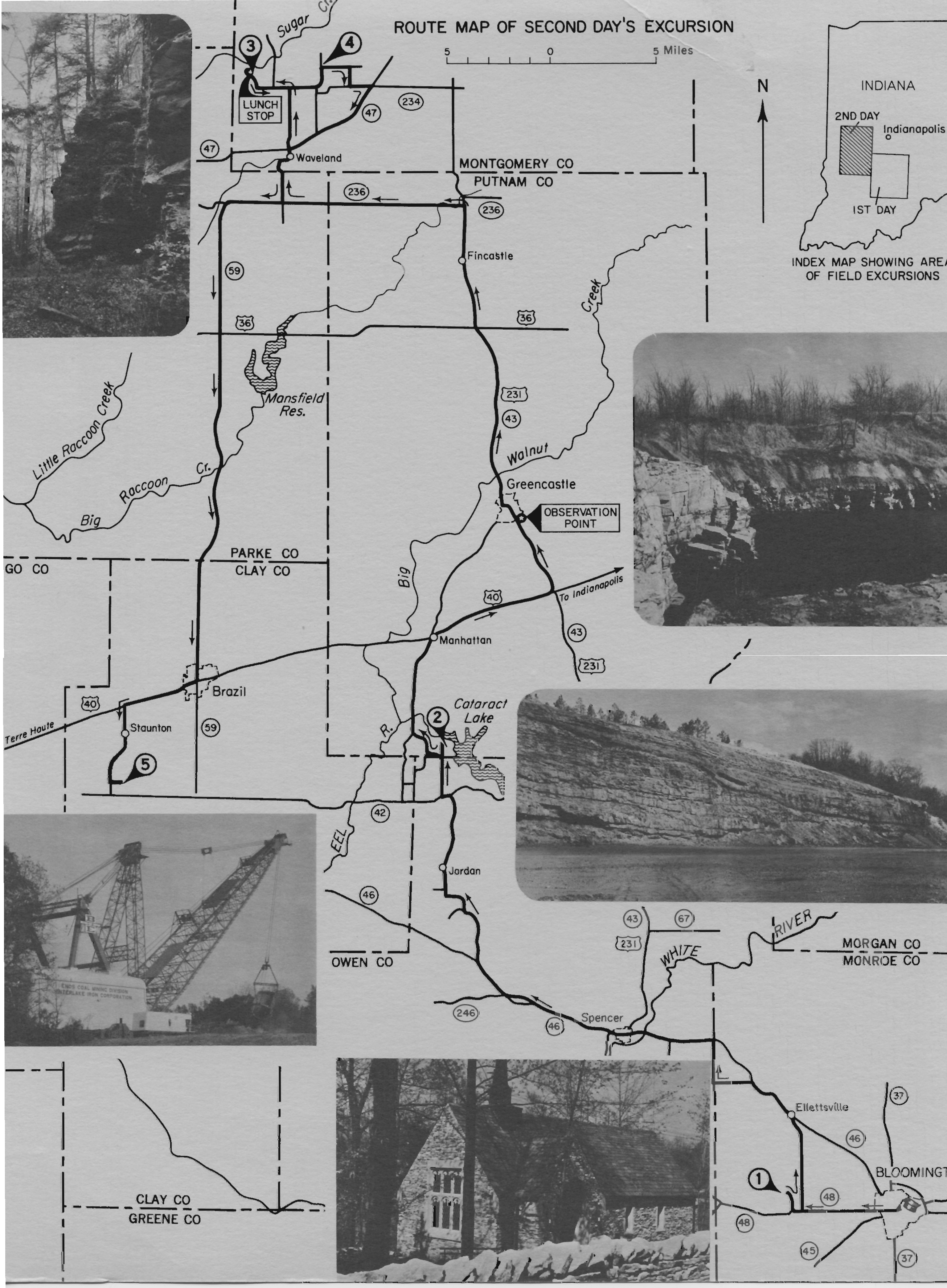
ROUTE MAP OF SECOND DAY'S EXCURSION
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INDEX MAP SHOWING AREA
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PUTNAM CO
Fincastle
Creek
Mansfield Res.
Little Raccoon Creek
Big Raccoon Cr.
Walnut
Greencastle
OBSERVATION POINT
PARKE CO
CLAY CO
GO CO
Big
To Indianapolis
Manhattan
Brazil
Terre Haute
Staunton
Cataract Lake
EEL R.
Jordan
OWEN CO
WHITE RIVER
MORGAN CO
MONROE CO
Spencer
Ellettsville
BLOOMINGT
CLAY CO
GREENE CO
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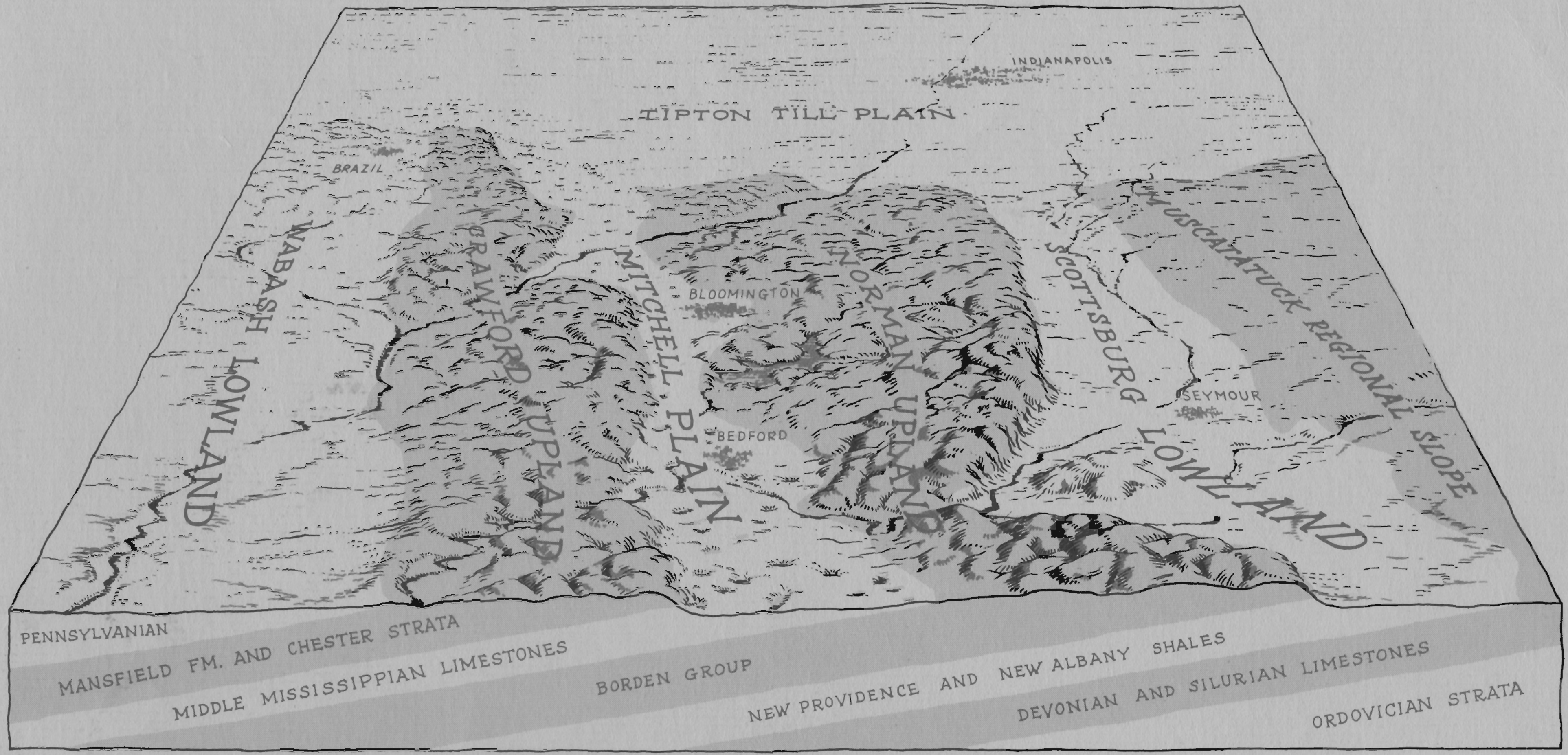

TIPTON TILL PLAIN
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CRAWFORD UPLAND
MITCHELL PLAIN
BLOOMINGTON
BEDFORD
NORMAN UPLAND
SCOTTSBURG LOWLAND
SEYMOUR
MUSCATATUCK REGIONAL SLOPE
PENNSYLVANIAN
MANSFIELD FM. AND CHESTER STRATA
MIDDLE MISSISSIPPIAN LIMESTONES
BORDEN GROUP
NEW PROVIDENCE AND NEW ALBANY SHALES
DEVONIAN AND SILURIAN LIMESTONES
ORDOVICIAN STRATA